

# INFORMATIONAL LEAFLET NO. 166

## KVICHAK RIVER SOCKEYE SALMON SMOLT STUDIES 1955 - 1972

By  
Robert Paulus  
and  
Kenneth Parker

---

STATE OF ALASKA

William A. Egan - Governor

DEPARTMENT OF FISH AND GAME

James W. Brooks, Commissioner

Subport Building, Juneau 99801



---

October 1974

KVICHAK RIVER SOCKEYE SALMON SMOLT STUDIES <sup>1/</sup>  
1955 - 1972

A historical review of sockeye salmon  
smolt research conducted on the  
Kvichak River, 1955-1972

by

Robert Paulus  
and  
Kenneth Parker  
Division of Commercial Fisheries  
Research Section  
Anchorage, Alaska

<sup>1/</sup> This investigation was partially financed by the Commercial Fisheries Research and Development Act (P.L. 88-309 and as amended) under project 5-5-R for the years 1965-1969 and the Anadromous Fish Act (P.L. 89-304 and as amended) under project AFC-21 and AFC-33 for the years 1970-1972.

## TABLE OF CONTENTS

	Page
LIST OF FIGURES . . . . .	i
ABSTRACT . . . . .	ii
INTRODUCTION . . . . .	1
INDEX PROGRAM, HISTORICAL REVIEW . . . . .	4
1955 - 1960 Operations . . . . .	4
1961 - 1965 Operations . . . . .	8
1966 - 1972 Operations . . . . .	11
TOTAL OUTMIGRATION ESTIMATE PROGRAM, HISTORICAL REVIEW . .	12
1965 Operation . . . . .	12
1966 Operation . . . . .	13
1967 Operation . . . . .	13
1968 Operation . . . . .	15
1969 Operation . . . . .	15
1970 Operation . . . . .	18
1971 Operation . . . . .	24
1972 Operation . . . . .	28
CONCLUSIONS . . . . .	32
LITERATURE CITED . . . . .	34
APPENDIX HISTORICAL TABLES (SMOLT) . . . . .	44

# LIST OF FIGURES

	Page
Figure 1. The Kvichak River drainage basin, Bristol Bay, Alaska . .	2
Figure 2. Upper Kvichak River sample sites, 1955-1972 . . . . .	5
Figure 3. Fyke net used in Kvichak River for assessing sockeye salmon smolt abundance, 1955-1959 . . . . .	7
Figure 4. Kvichak River sockeye salmon smolt outmigration periods and ice occurrence, 1957-1972 . . . . .	9
Figure 5. Photo-counter assembly used for Kvichak River index program, 1962-1972 . . . . .	10
Figure 6. Kvichak River sockeye salmon smolt study area, 1967- 1969 . . . . .	14
Figure 7. Nylon fyke net and live box used to capture sockeye salmon smolt for mark and recapture study, 1967-1968 . .	16
Figure 8. Isometric view of the migrant dipper designed for smolt recapture operation at the Big Rock sample site on the Kvichak River, 1968 . . . . .	17
Figure 9. Schematic diagram of smolt gill net arrays used in Kvichak River smolt distribution study, May-June 1969 . . . . .	19
Figure 10. One section of 1970 smolt sonar array . . . . .	21
Figure 11. Schematic of the Bendix 1970 smolt counter sonar array, side view, drawing not to scale . . . . .	22
Figure 12. Schematic of the Bendix 1970 smolt counter array, top view, drawing not to scale . . . . .	23
Figure 13. Details of the Bendix smolt sonar transducer arrangement, 1971 model . . . . .	25
Figure 14. Percent of total outmigration by day as measured at index and sonar, 1971 . . . . .	29

LIST OF FIGURES (cont.)

	Page
Figure 15. 1972 sonar smolt counter with depth and velocity controls, left and right - upper and lower digit counters, transducer signal lights, and 4 column printer . . . . .	31

## ABSTRACT

The Kvichak River smolt study was initiated to establish a basis for accurate prediction of returning adult run size and to arrive at an estimate of the optimum annual escapement needed to reach maximum sustained yield for the Kvichak fishery. The program has attempted to accomplish this by providing an estimate of the total annual smolt outmigration and by continuing the collection of data on age and size of smolt. During development of total outmigration hardware and techniques, an existing smolt index program was continued to facilitate its eventual relation to total outmigration estimates. Various methods of smolt population enumeration were evaluated during the life of the study with many proving unusable. In 1970 experiments were conducted testing the feasibility of utilizing underwater sonar counting equipment in the Kvichak River. Three sonar models were designed by the Bendix Corporation and field tested by Alaska Department of Fish and Game, Commercial Fisheries Research personnel. As a result, the Kvichak watershed's first total sockeye salmon smolt outmigration estimates were computed for 1971 and 1972.

# KVICHAK RIVER SOCKEYE SALMON SMOLT STUDIES 1955 - 1972

By

Robert D. Paulus, Region Research Supervisor  
and

Kenneth P. Parker, Fishery Biologist  
Alaska Department of Fish and Game  
Division of Commercial Fisheries  
Anchorage, Alaska

## INTRODUCTION

The Kvichak River drainage basin covers nearly 8,000 square miles, and includes two major lakes. Iliamna Lake, the largest freshwater lake in Alaska, is 80 miles long, 20 miles wide, and 1,115 square miles in area (Figure 1). Iliamna Lake is about 50 feet above sea level with a maximum depth of 988 feet and an average depth of 144 feet. Lake Clark is about 220 feet above sea level with a maximum depth of 860 feet, and an average depth of 338 feet, (Burgner, 1969).

The Kvichak River drainage is the single most important sockeye salmon producing system in Bristol Bay. Of the approximately 616 million sockeye salmon caught commercially in the Bay since 1914, 391 million or 63.5 percent were taken in the Naknek-Kvichak district to which the Kvichak is the major contributor.

Not only is this fishery extremely important to the economy of the local Bristol Bay area and the State of Alaska, its management is of increasing international significance. Accurate predictions and estimates of annual optimum escapements are needed in discussions with the Japanese government relative to their high seas salmon fishery. In addition, scientific management and research are requirements of the abstention principal of the International North Pacific Fisheries Treaty.

A factor emphasizing the need for research was the annual variation in production from this system. In recent years, adult sockeye salmon returns to the Kvichak have varied from a low of 319,461 fish to a high of 54,038,493 fish. Successful management of this resource requires a knowledge of the causes of this large cyclic variation and some method of anticipating and predicting the variation in future returning runs. Accurate predictions are

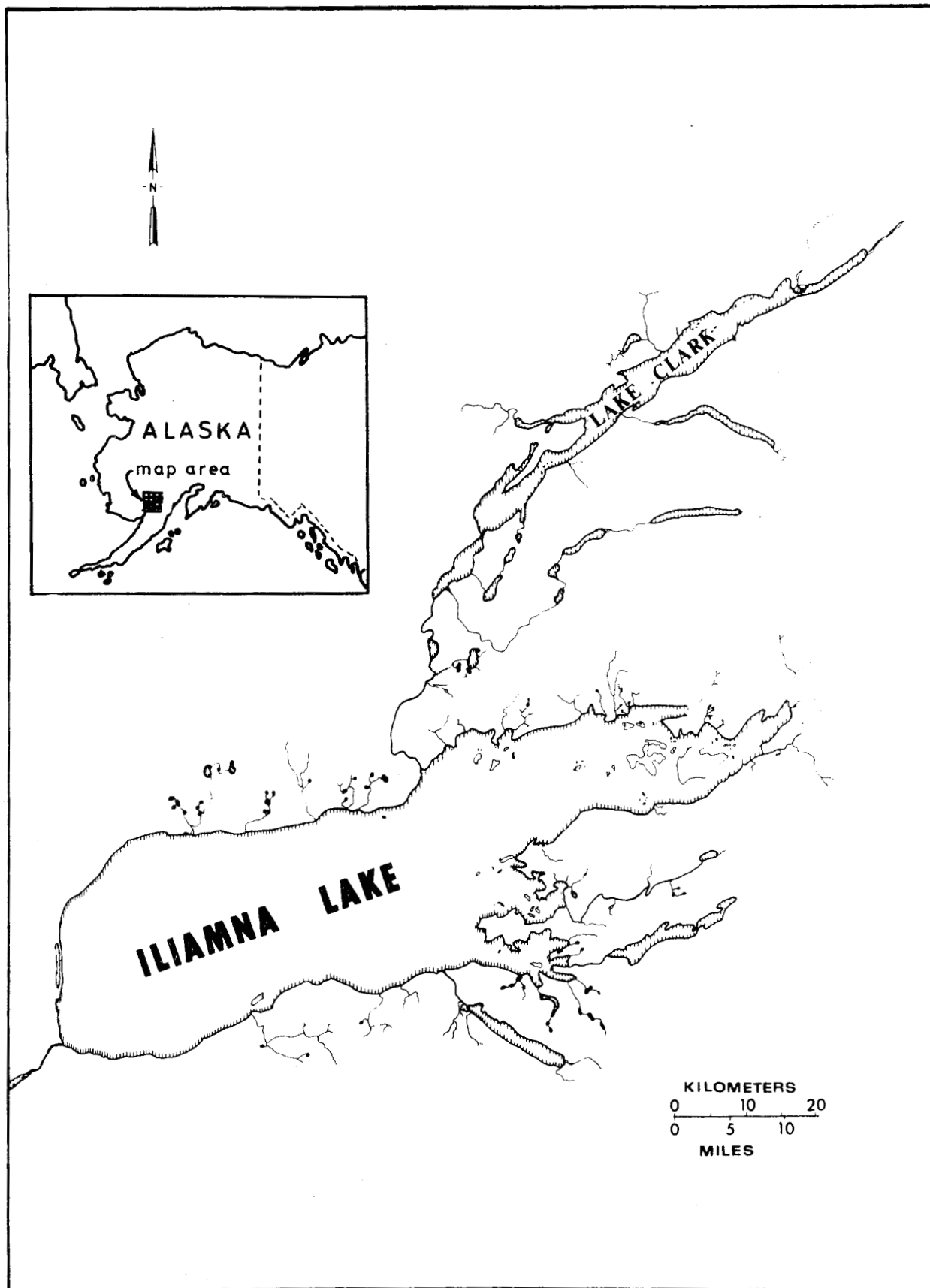


Figure 1. The Kvichak River drainage basin, Bristol Bay, Alaska.

also necessary for the fishing industry to estimate production facilities needed to harvest the run.

This need for more data resulted in the initiation in 1955 of a research program under the supervision of the Fisheries Research Institute of the University of Washington encompassing spawning and rearing area, escapement, and smolt studies. Since 1961, the smolt study and since 1960 the escapement enumeration and sampling have been the responsibility of the Alaska Department of Fish and Game.

The Kvichak smolt project was initiated to evaluate the relative smolt production from various sized escapements and to obtain information on age and size of smolt. The smolt indices of abundance obtained in this study have been used to predict adult returns since, in general, they have yielded a better relationship to return than escapement data have. However, the long range goal of these studies was to obtain a more complete understanding of cycle mechanisms and their implications in managing the escapements to obtain maximum yield.

The most accurate prediction of adult run size attainable from inshore data may logically be sought by a program of smolt enumeration and study. At this stage of life history, the highly variable freshwater mortality has already had its effect and can be measured. Also, the fish to be enumerated are concentrated in the relatively small area of a single river as compared to their distribution throughout Lake Iliamna as fry or, later, as maturing fish throughout the ocean. However, an existing smolt index project did not adequately fulfill these objectives as is evidenced by the variable accuracy of the prediction. While some variation could be expected in high seas mortality, it is reasonable to presume that a precise measurement of outmigration magnitude and age composition would lead to improved forecast accuracy.

The Kvichak smolt index project was basically a pilot study on the problems and possibilities of smolt enumeration. However, due mainly to a lack of funds, it did not proceed beyond that stage, except for a few minor embellishments until Federal funding was introduced. Although the use of photo-counters and 24-hour fishing were incorporated into the project, fishing was still conducted with a single fyke net in one of the original locations. A greatly expanded smolt study was needed to improve the accuracy of the smolt migration enumeration.

In 1965 a partially federally funded program using funds from Commercial Fisheries Research and Development Act (P.L. 88-309), was initiated to improve the index or obtain an outmigration estimate suitable for forecast application. Beginning with fiscal year 1969-70 the program funding was

switched to the Anadromous Fish Act (P.L. 89-304).

Under the partially federally funded program, research was directed toward the development of total outmigration hardware and techniques while the index program was continued because of the possibility that it could eventually be statistically related to total outmigration estimates, and because it was the only inventory method available.

The purpose of this report is to give a historical account of the development and evolution of the Kvichak River index and total outmigration programs.

## INDEX PROGRAM, HISTORICAL REVIEW

### 1955-1960 Operations

Beginning in 1947, information on sex and age composition of adult salmon was collected from the commercial catch and spawning ground escapements of the Kvichak watershed. The work was done by the Fisheries Research Institute, University of Washington, and continued annually through 1954. In the spring of 1955, that organization, prompted by the Alaska Salmon Industry, Inc., began studies of the Kvichak sockeye runs in an attempt to locate sources of mortality in various life stages. At that time, the smolt index program was established, (Kerns, 1961) by FRI on Saltonstall-Kennedy funds administered by the U.S. Bureau of Commercial Fisheries (now National Marine Fisheries Service).

Potential smolt sampling sites were selected from the upper 4 miles of the Kvichak River, where water depth and velocity, smolt concentration, and crew maintenance logistics were optimal (Figure 2). Below the 4-mile area, the river breaks up into a multitude of channels in Kaskanak Flats, then reconsolidates into the slower, deep river channel that continues to the upper reaches of tidal influence below Kaskanak Flats. Fyke net sampling gear chosen for this program could not be fished in deep water or water with low velocities.

In the areas where sites were selected, the river channel varies from 500 to 700 feet wide, and up to 15 feet deep. The river bottom above Kaskanak Flats is characteristically gravel of 1 inch to 2 inches, with larger material showing in fast deep channels. The water is normally clear with the mid-channel velocity ranging up to 7 or 8 feet per second.

Sites A, B, and C were 1/2, 4 and 2 miles respectively from the lake. In these sites, a net location was sought where water velocities were 3.1 f.p.s. or greater, since tests showed that lower velocity seemed to result in decreased catches.

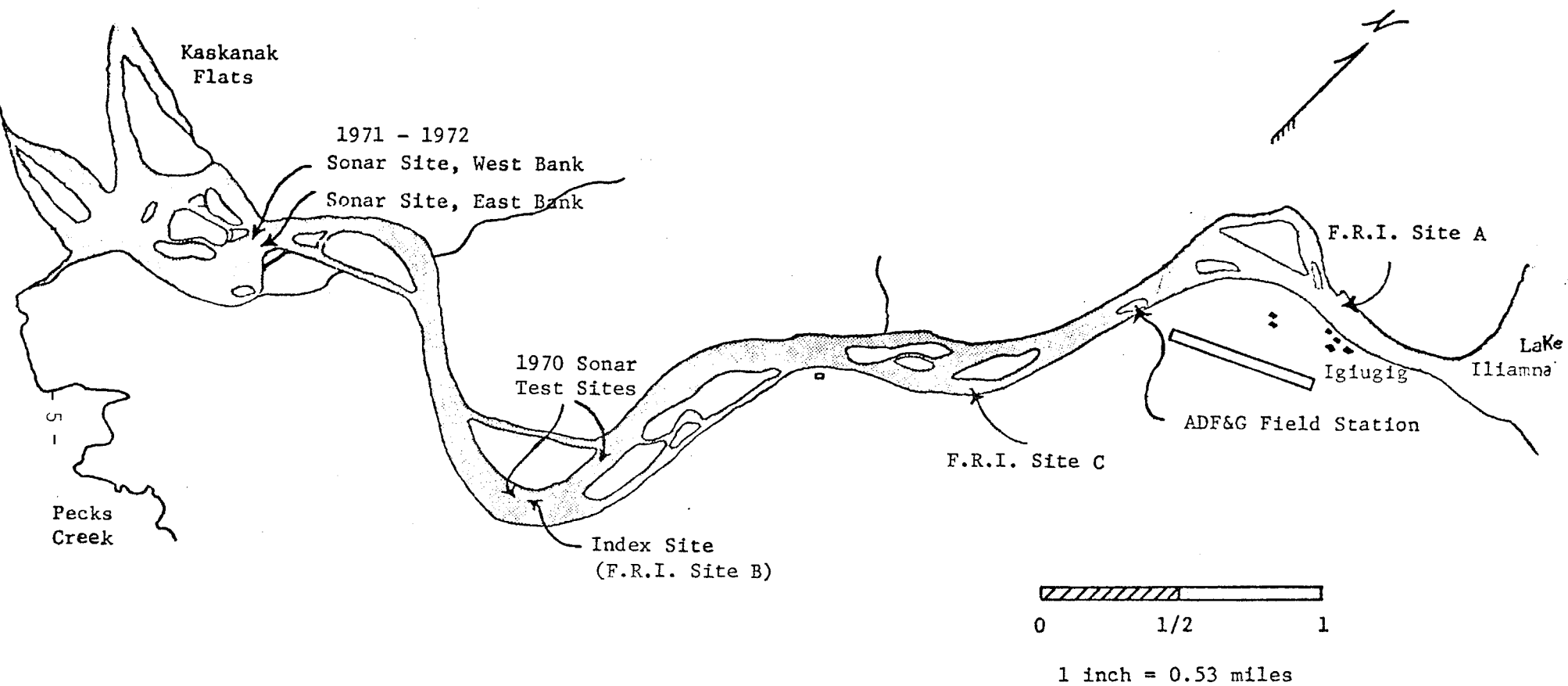


Figure 2. Upper Kvichak River sample sites, 1955-1972.

Gear chosen for this program was a fyke net fitted with knotted 1-inch stretched measure cotton webbing, (Figure 3). The net was sewn to a rigid 4' x 4' square tubular steel frame. Running upstream and outward from the frame were two wings 10' long and 4' high. Wings were held open at a width of 9 feet by water current, and restricted at that width by two spreader lines. Wings were stretched vertically by corks and leadlines. Behind the frame the body of the net narrowed, in 4 feet of length, to an 18 inch diameter restriction, within which was a webbing throat of 1/2 inch stretched measure mesh and a 2" x 10" metal frame. The metal frame in the throat prohibited fish from retracing their path of entry and escaping the net. Back of the "throat" was a removable cod-end to facilitate sampling of the catch, (Kerns, 1961). The gear design remained similar through the life of the project, although netting materials eventually changed to nylon. The net was held in place with separate anchor lines attached to bridles on each wing. Water depth was set at 3.8 feet.

In general, site B was used to attain the index, with accessory fishing at sites A and C. Methods of fishing are thoroughly discussed in Kerns, 1961.

Briefly, the fishing season continued from the time of lake breakup through the period of rapid increase of water temperature, until smolt catches practically ceased. This period is usually from May 15 to June 15.

In these early years fishing was done during the darkest period of the night only, from 2200 to 0100 hours, since observations on the nearby Nushagak River indicated most of the daily outmigration took place during those hours. This was substantiated on 24-hour sampling days on the Kvichak in 1957, 1958, and 1960.

Age, length, weight, and relative numbers of emigrating smolt were determined from the catches made in the fyke net during sampling period, (Kerns, 1961).

From analysis of the age-length information an age class separation point was determined and applied to the length frequency samples to establish the age class composition of the outmigration. Sockeye salmon smolt are aged according to the number of winters spent in lake residence prior to emigration. Therefore, Age I smolt would have spent 1 year in lake residence prior to smoltification, while Age II smolt would have spent 2 years. Because of the 1 year separation of age classes, smolt can readily be separated by age class according to their lengths (snout to fork) once the separation point is known.

Catch rates and length frequencies of smolt in catches at sites A and

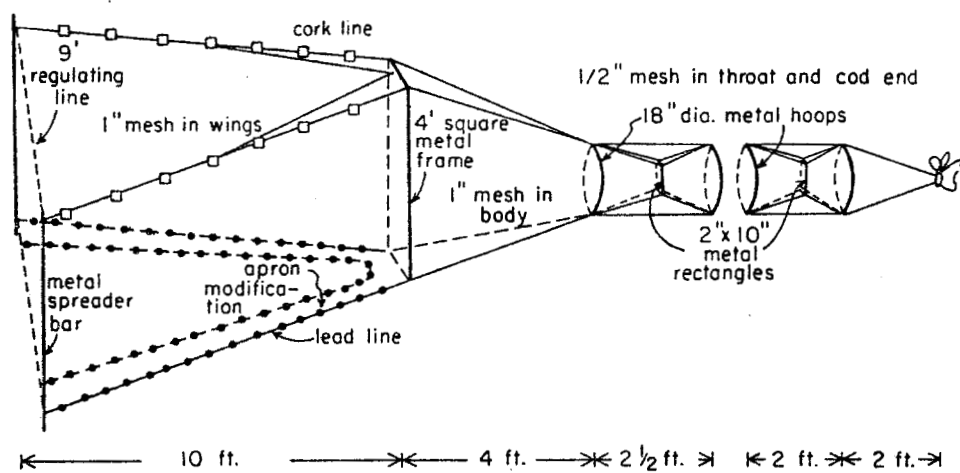


Figure 3. Fyke net used in Kvichak River for assessing sockeye salmon smolt abundance, 1955 through 1959.

B were found to be substantially different. The differential catches showed the site with greater velocity produced catches of more pounds per hour and smolt of larger average size, indicating that net avoidance was decreased in faster water, especially for the larger smolt (Kerns, 1961).

Throughout the years of this program, the question of percentage of smolt emigrating during the three index hours was checked only in 1955, 1958 and 1959 with 24-hour fishing days. Estimates were not recorded on daytime vs. nighttime avoidance. Because of the timing of smolt outmigration, ice interfered with fishing several days out of each year, requiring estimates be made of missed numbers of fish. Days missed due to ice during smolt outmigrations are illustrated in Figure 4.

In 1959, Veeder-Root photo-electric counters were introduced as counting equipment. The units were installed in a funnel-shaped aluminum tunnel at the rear of the fyke net. The photo-electric equipment consists of Veeder-Root Series A-180707 electronic counter, a heavy-duty 12 volt battery, a Heath kit Model No. MP-10 power converter, and the photo-cells mounted in the tunnel (Figure 5). Testing was continued and refinements made in 1960 (Kerns, Koo, and Junge, 1961).

#### 1961-1965 Operations

The smolt sampling program on the Kvichak River was similar in 1961 to the previous years, except that the program became the responsibility of the Alaska Department of Fish and Game with the coming of statehood. Some 24-hour sampling was conducted (Church, 1963). In that year, also, the FRI began work on spawning and nursery areas and juvenile sockeye in the Kvichak watershed (Mathisen & Kerns, 1964).

In the following year, 1962, the Kvichak smolt program was conducted by FRI under contract to Alaska Department of Fish and Game. The photo-counter equipment was again used at the rear of the fyke net (Kerns and Marriott, 1963). With this unit attached and the cod-end removed, the net was fished 24 hours a day during the ice free periods to get an estimate of total daily passage without a fulltime staff on hand. While in previous 24-hour fishing the net required a cod-end to measure passage, and frequent emptying to prevent extremely high mortality of the catch, the fish now passed through the counter and continued their outmigration.

During calibration periods only, a cod-end was affixed behind the photo-counter to determine the average fish per count ratio. To estimate the number of fish in the catch, the cod-end catch was weighed, and the number of fish in a

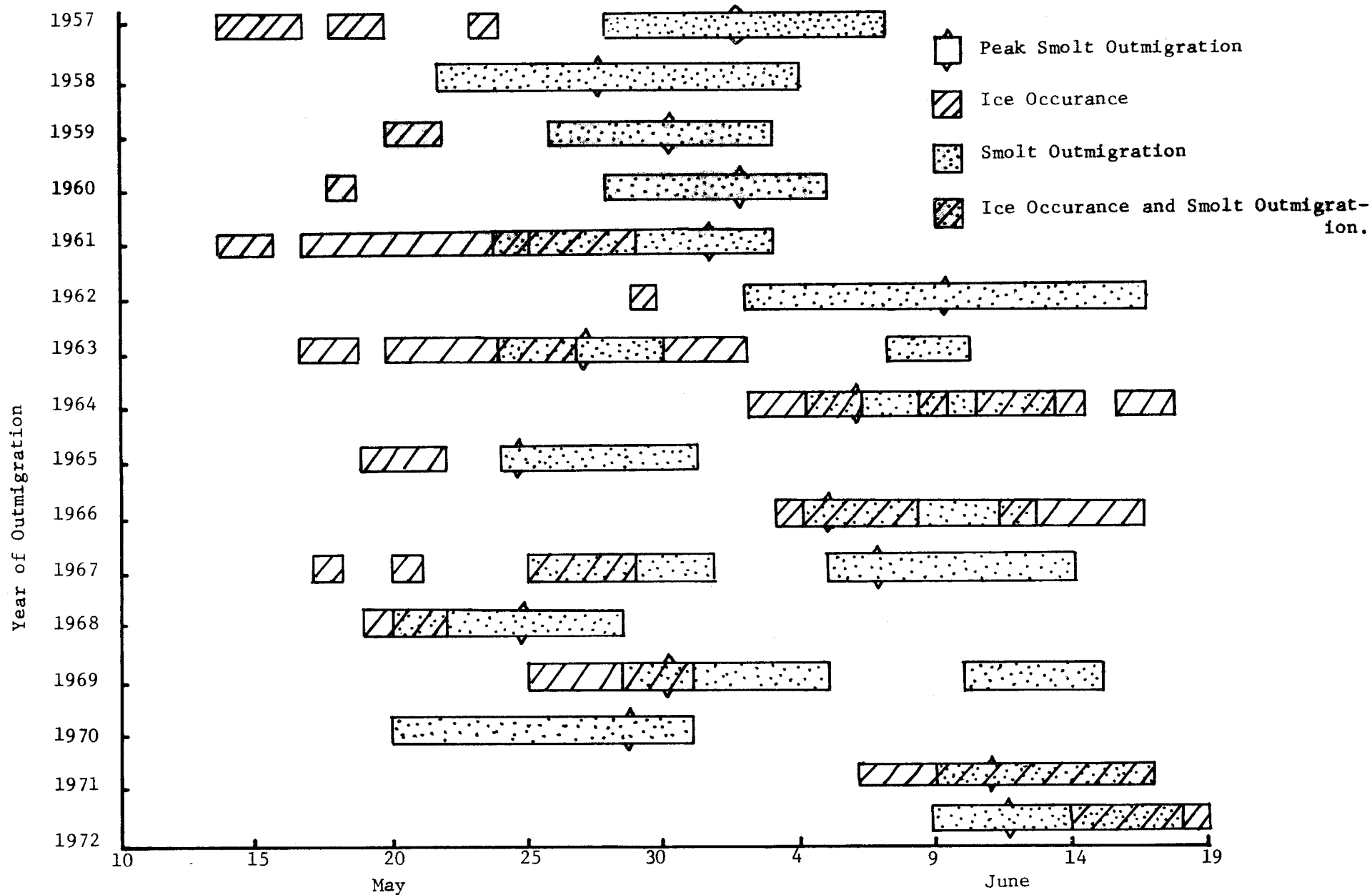


Figure 4. Kvichak River sockeye salmon smolt outmigration periods and ice occurrence, 1957 - 1972.

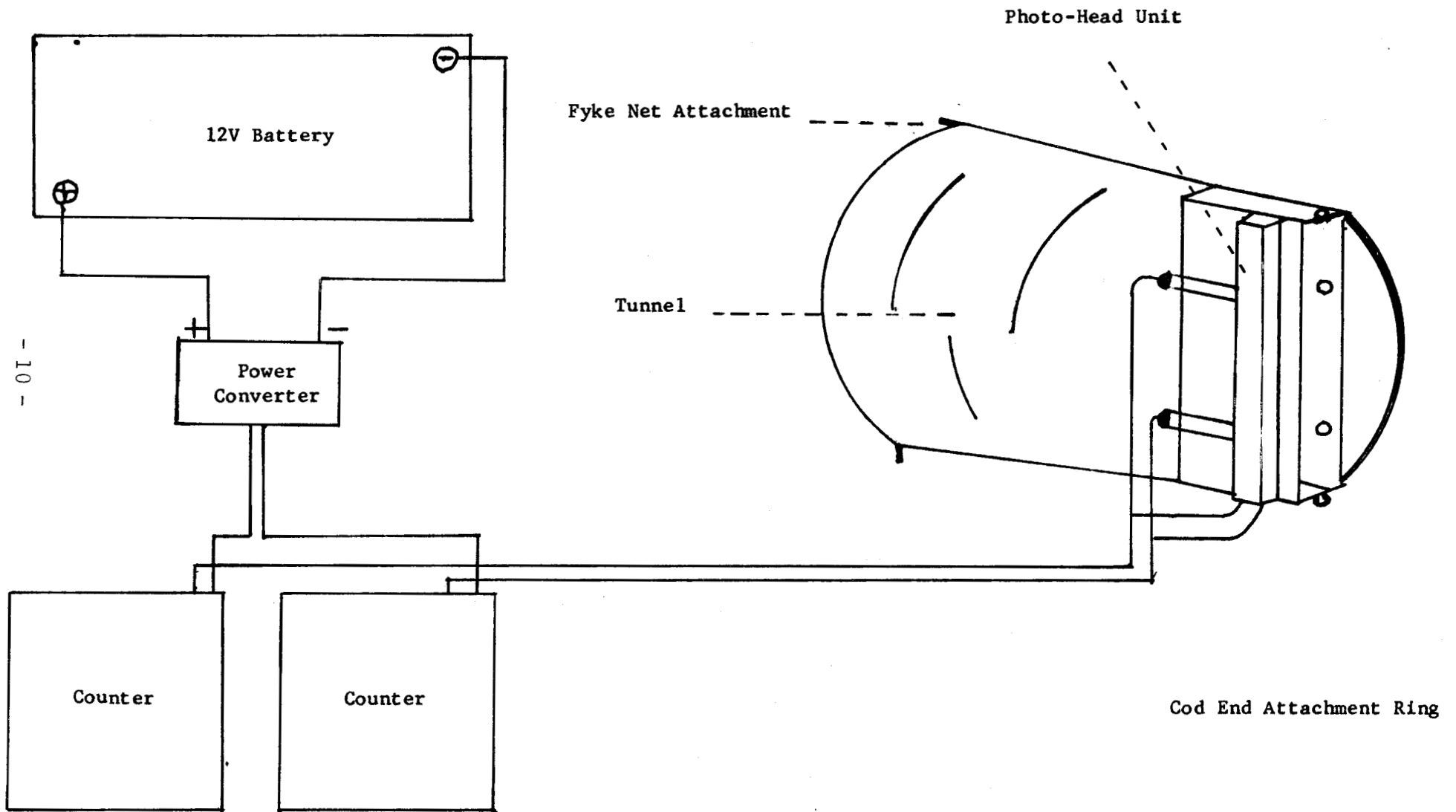


Figure 5. Photo-counter assembly used for Kvichak River index program, 1962 - 1972.

random 1 lb. sample, was counted. The fish per pound from the sample was multiplied by total pounds of catch, and that figure divided by the number of counts registered on the photo-counter. The result was the f.p.c. (fish per count) ratio. The average of these f.p.c. calibrations was applied to counts to determine passage for periods when the cod-end was not attached. Complete methodology is discussed in Marriott (1965).

Following the 1962 season, the variation between years in the ratio of the 3-hour index catch to the 24-hour index catch was studied. The conclusion was that the 3-hour proportion of the 24-hour outmigration as measured by fyke net, had ranged from 82.3 percent in 1957 to a low of 25.1 percent in 1962. It was apparent that the 3-hour index period count could not be relied upon to give an estimate of daily (thus seasonal) outmigration. The standard 3-hour index was replaced with two 24-hour sampling programs.

In 1963 the index operation was a 24-hour-a-day fyke net photo-tunnel operation that varied from the 1962 method in that the photo-electric cells in the tunnel were reduced from five to two pairs (Marriott, 1965). Climatological observations were begun that season. Water temperatures were considered to be one of the most valuable keys to beginning and ending dates of outmigration. This matter is discussed by Foerster (1968) in his text on sockeye salmon.

The 1964 season was again fyke net and photo-counter operation (Pennoyer and Seibel, 1965). The report on the 1964 season defines the conversion of 3-hour to 24-hour indices, and thoroughly documents use of the photo-electric equipment, sample collection, and interpolation for missed fishing periods.

During a normal smolt indexing season, fishing begins with 3 or 4 hours of fishing daily during the evening hours, until the first smolt are caught. Fishing then goes on 24-hours a day until smolt are essentially gone. During this period a fyke net is fished with a photo-tunnel or cod-end, and smolt are sampled daily for age class, length frequency, and weight. Samples are usually taken each hour during the "index hours", 2200 to 0100. Sample data is applied to daily index counts to come up with weighted numbers of smolt by age class with respective mean weights and lengths.

#### 1966-1972 Operation

The index operation from 1966 through 1972 remained unchanged with three minor exceptions. About 1966 the first nylon net was introduced when cotton became obsolete as a net fiber. The nylon was much more resistant to ice damage and storage decay. All cotton nets were replaced with nylon by the spring of 1971.

Another change was the addition of a lever mounted on the skiff gunwale for lifting the rear of the fyke net for cod-end servicing in 1969. This was the first move toward more rapidly cutting off the flow of smolt into the cod-end during calibrations. A final change was introduced with the inclusion of a manually controlled cod-end bypass gate in 1971. With the flip of a handle a shutter swung inward into the photo-tunnel restriction, cutting off the flow of fish from the photo-counters to the cod-end and shunting them through an exit on the side of the tunnel. This further improved the integrity of the smolt sample measured at the end of calibration by preventing uncounted stragglers from dumping into the cod-end.

The period 1966 through 1972 was a time of changing emphasis on the Kvichak smolt program from the indexing by fyke net to methods which could give a total outmigration estimate, or at the very least overcome the major problems in reaching a comparable annual index. Federal funds were introduced for this purpose in the 1966 field work, leading to the work reported in the total outmigration phase reported in this paper. The index program, however, remained basically unchanged.

Beginning in 1966, fyke-netting problems that could result in dissimilar ratios of index catch to outmigration were frequently cited. Ice interference was cited in each report from 1966 through 1972. Changes in net avoidance by smolt was mentioned in some early years, and annually beginning in 1967 due to water turbidity and light. Dissimilar distribution of smolt was documented in 1961 by Kerns, as cited earlier and again in the 1970 smolt report. Differences in distribution by age class were not found in 1955, 1957 and 1958, but were observed in 1970, 1971 and 1972.

Annual reports document the programs for 1965 (Pennoyer, 1966), 1966 (Pennoyer and Stewart, 1967), 1967 (Pennoyer and Stewart, 1969), 1968 (Paulus and McCurdy, 1969), 1969 (McCurdy and Paulus, 1972), 1970 (Paulus and McCurdy, 1972), 1971 (Russell, 1972), and 1972 (Parker, 1974). Data from the index program is presented in Appendix Tables 1-9 with related spawner numbers.

## TOTAL OUTMIGRATION ESTIMATE PROGRAM, HISTORICAL REVIEW

### 1965 Operation

Investigations in 1965 were separated into two phases. Phase I involved the initiation of a literature survey and compilation of available information on sockeye salmon smolt and downstream migrant sampling equipment. Phase II involved the location and selection of a suitable sampling site on the Kvichak

River where an estimation of total sockeye salmon smolt outmigration could be obtained. Physical and biological parameters examined at potential sites included river width, depth, current velocities, bottom profiles, ice occurrence and smolt presence (Pennoyer, 1966).

#### 1966 Operation

During the 1966 field season, efforts continued to establish a sample site on the Kvichak River where a total outmigration estimate could be made. It was concluded that an acceptable site would have to be relatively free from ice to facilitate continuous sampling during the relatively short outmigration periods. With this as a main criteria for acceptance, a portion of the Kvichak River 15 miles downstream from Kaskanak Flats was selected. The sample site known as Big Rock exhibited the required characteristics of uniform river bottom, fairly straight channel and absence of ice (Figure 6). From analysis of physical data collected at Big Rock site, it was concluded that sampling to obtain an outmigration estimate at that location would present some unique problems. Low current velocities, tidal reversals of current and depth of the river represent the primary difficulties and precluded the utilization of conventional stationary sampling gear (Pennoyer, 1967). A review of the problem involved, gear required, and data needed, was undertaken to determine the feasibility of obtaining an outmigration estimate under these sampling conditions.

During the same season, fyke net sampling at Otter Island was also conducted, but heavy ice run out from Lake Iliamna disrupted fishing for several days, and the area was not considered usable as a total outmigration site.

Under Phase I of this project the literature review was directed toward examining gear types and sampling designs used for enumerating downstream migrants in similar circumstances elsewhere.

#### 1967 Operation

Two approaches for obtaining an estimate of the total outmigration were tested during the 1967 field season. The first method, a volumetric analysis, was based on estimates of smolt passage rates expressed in catch per volume of water versus total flow. The capture gear designed and used for the above method was not effective due to smolt avoidance. Thus, this method was abandoned, (Pennoyer and Stewart, 1969; Paulus and McCurdy, 1969).

The second method was a mark-recapture method utilizing compressed air and a fluorescent pigment to mark smolt. The pigment was applied to the young

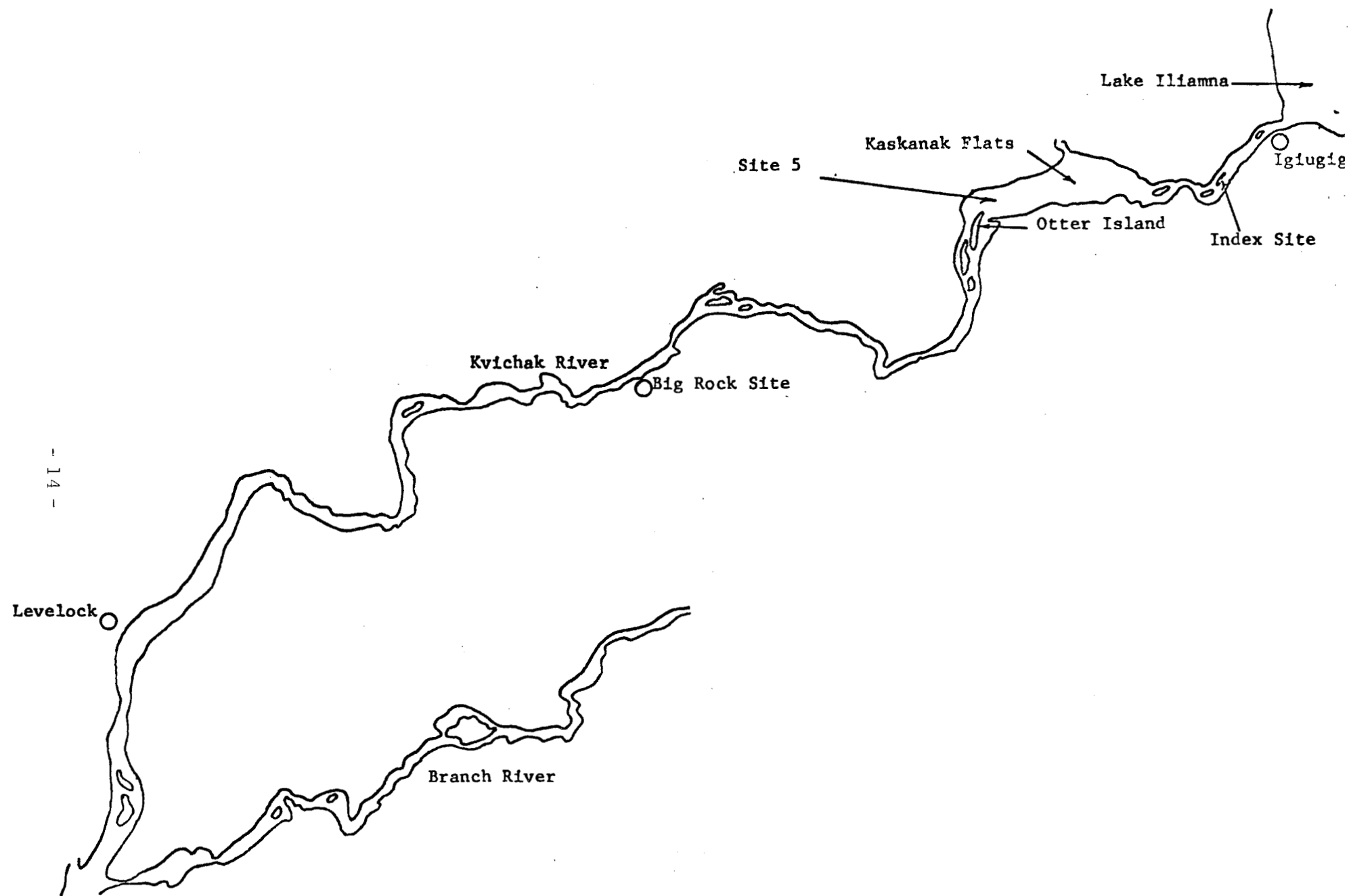


Figure 6. Kvichak River sockeye salmon smolt study area, 1967 - 1969.

salmonids with the aid of a sandblast gun and delivered at 100 p.s.i. pressure. Capture of smolt for marking was conducted at the index site by funneling smolt through a standard 4' x 4' fyke net and into a floating live box (Figure 7).

Smolt recapture was conducted 25 miles downstream at the Big Rock site (Figure 6). Recovery gear consisted of two nets with a 9 square foot opening and no wings. Recaptured smolt were then examined under an ultraviolet light for presence of the fluorescent pigment.

Results from the 1967 field season indicated that the two net recovery program did not lend itself to a total population estimate (Pennoyer and Stewart, 1969). However, it was thought that the mark and recapture method of population estimation was feasible. For this reason, efforts were directed toward investigating other forms of capture gear. Of prime consideration was a migrant dipper sampling device developed by the Montlake Laboratory, National Marine Fisheries Service, Seattle, for use at low current velocities.

#### 1968 Operation

Mark and recapture sampling was repeated during the 1968 field season. Sampling methods were similar to those used in 1967 with two exceptions. First, smolt marking and release locations were moved to Kaskanak Flats (Figure 6). Second, a migrant dipper (Figure 8) was tested and evaluated for smolt recapture at the Big Rock site.

Numerous difficulties were experienced during the recapture effort at the Big Rock site. Due to excessive water resistance caused by the migrant smolt dipper, mobility was practically impossible except for brief periods during slack water in this tidally-influenced area (Paulus and McCurdy, 1968).

In addition to mechanical difficulties with the recapture gear, the smolt frequently formed meandering, ribbon-like schools that did not enter the gear. It became apparent that much information on smolt distribution and behavior was required before enumeration efforts of this type could be relied upon for total outmigration information.

#### 1969 Operation

Under Phase I of the Kvichak River smolt studies, research was directed toward investigating the feasibility of sonar counting devices for measuring smolt outmigration. Mr. Albert Menin of the Bendix Corporation was consulted for information on this subject. During the field season, Mr. Menin conducted

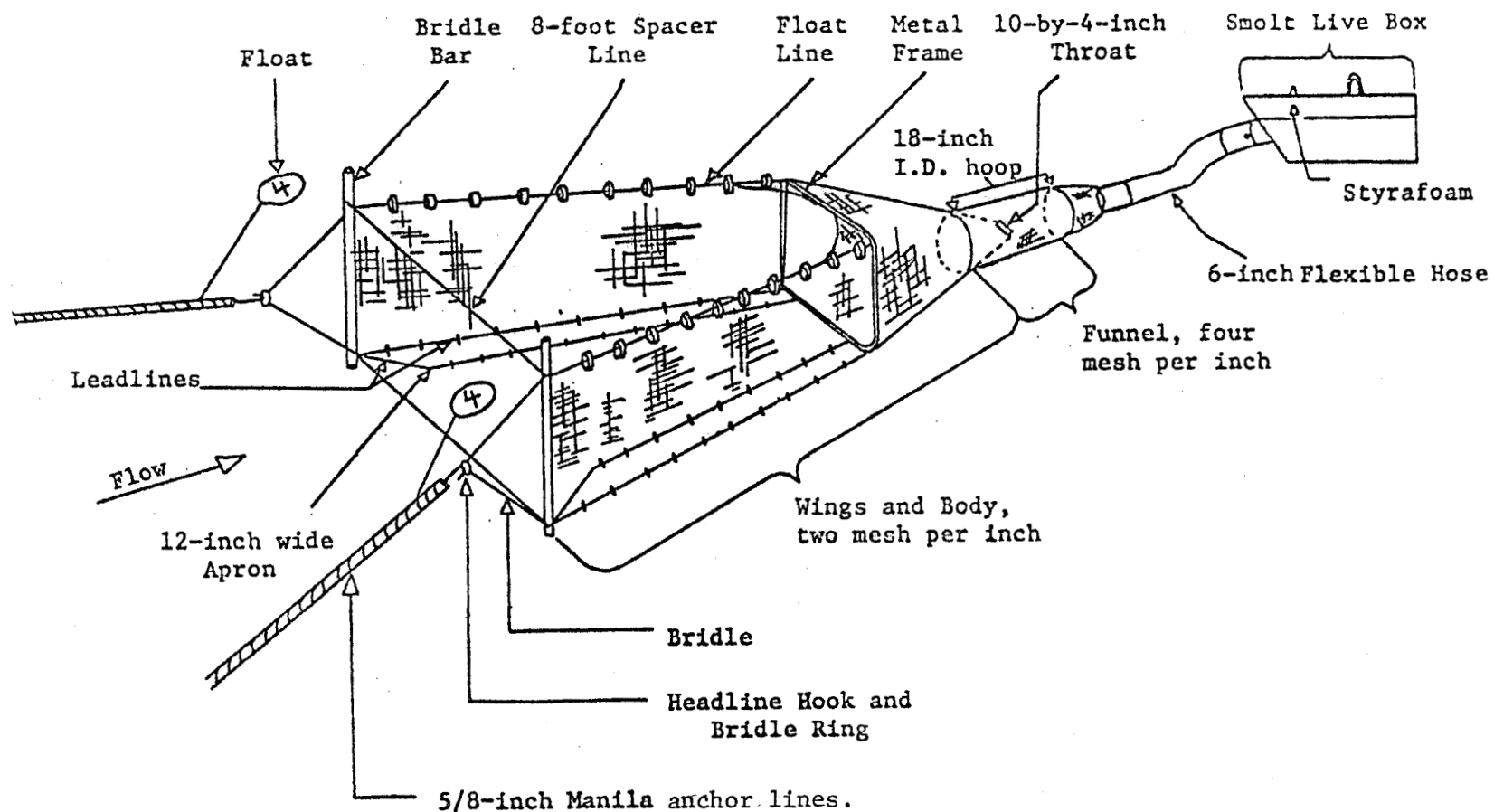


Figure 7. Nylon fyke net and live box used to capture sockeye salmon smolt for mark and recapture study, 1967-1968.

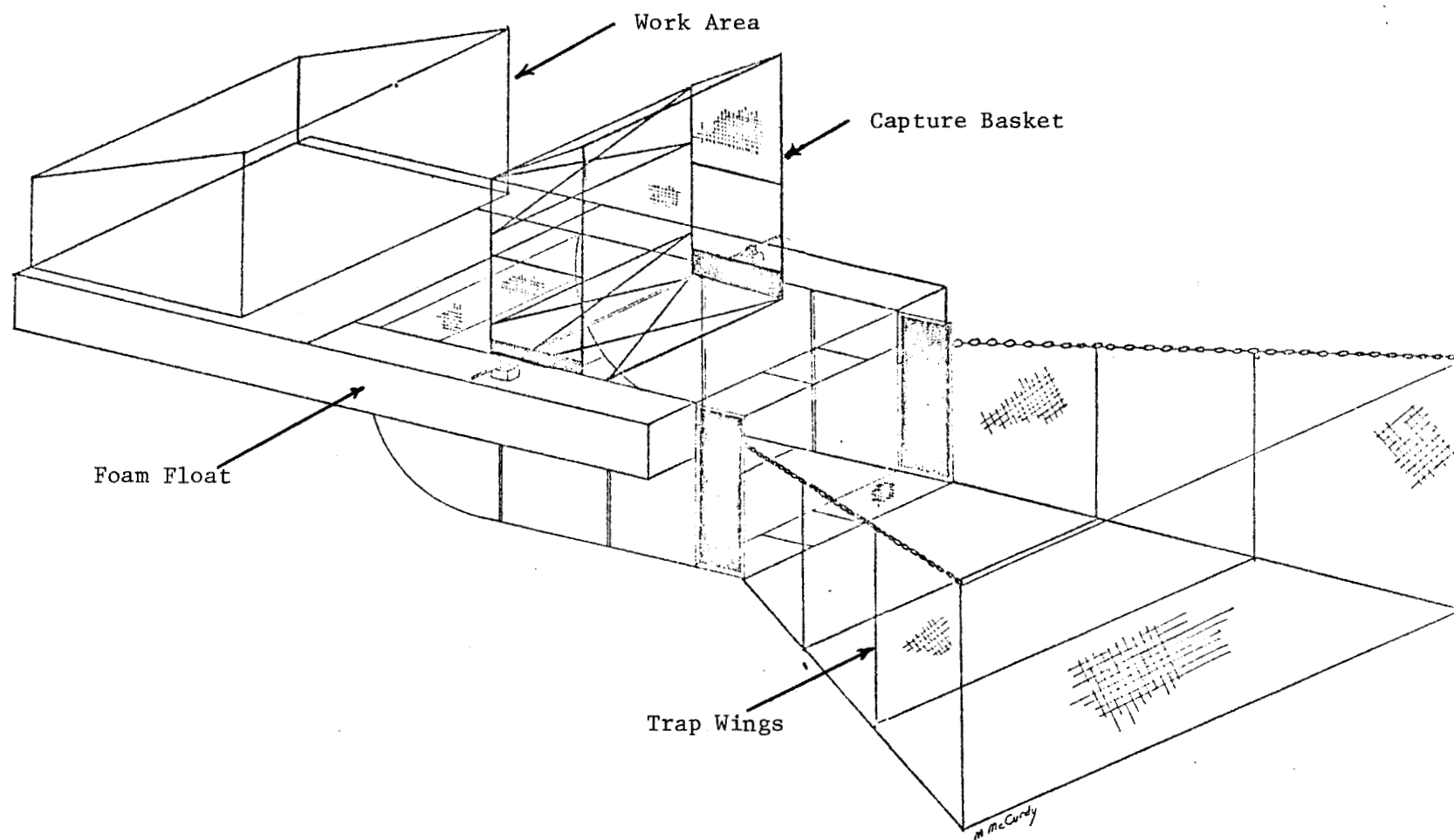


Figure 8. Isometric view of the migrant dipper designed for smolt recapture operation at the Big Rock sample site on the Kvichak River, 1968.

several experiments on the Kvichak River to determine the "countability" of sockeye salmon smolt. The results from these experiments indicated sonar counting devices could be applied to counting outmigration smolt. Plans were formulated for the construction of two sonar counting units which would be in operation the 1970 field season.

In 1969 there was no field program conducted to obtain a total outmigration estimate. Instead three programs of an experimental nature were conducted. The first, an index improvement and evaluation program at Kas-kanak Flats was conducted to observe daily index catches as to number and age composition and to determine the fishability of a metal fyke trap.

The second program investigated utilization of the metal fyke trap as a calibrating device for a sonar smolt counter. This was to be accomplished by positioning the metal trap directly behind the sonar counting gear. A photo-electric counter was to be connected to the restriction of the metal trap thus obtaining an enumeration of the fish passing over the sonar arrays and then through the trap.

Numerous difficulties encountered with the metal fyke trap forced an early termination of all related projects. Consequently no true evaluation was obtained for 1969 (McCurdy and Paulus, 1972).

The third program initiated in 1969 involved assessing orientation of smolt within the stream cross-section or velocity profile by age class throughout the outmigration period. The information acquired from this distributional study would be directly applicable to designing sampling equipment and procedures for any total outmigration monitoring program. The sampling gear consisted of 1/2 inch monofilament knotless gillnet hung in panels 2' x 1.5' and spaced 1 foot apart in a vertical array (Figure 9). The arrays were then spaced evenly across the river, and hung from a surface "header-line" (McCurdy and Paulus, 1972).

Throughout the season very few fish were actually captured with the equipment preventing any assessment of smolt distribution. It appeared that the observed small catch was primarily the result of the low magnitude of outmigration in 1969 (McCurdy and Paulus, 1972).

#### 1970 Operation

As a result of the 1969 sonar experiments, construction of the first sonar counting system began at the Bendix laboratories in California. Initial tests on the transducers were made at the Nimbus Hatchery in Sacramento,

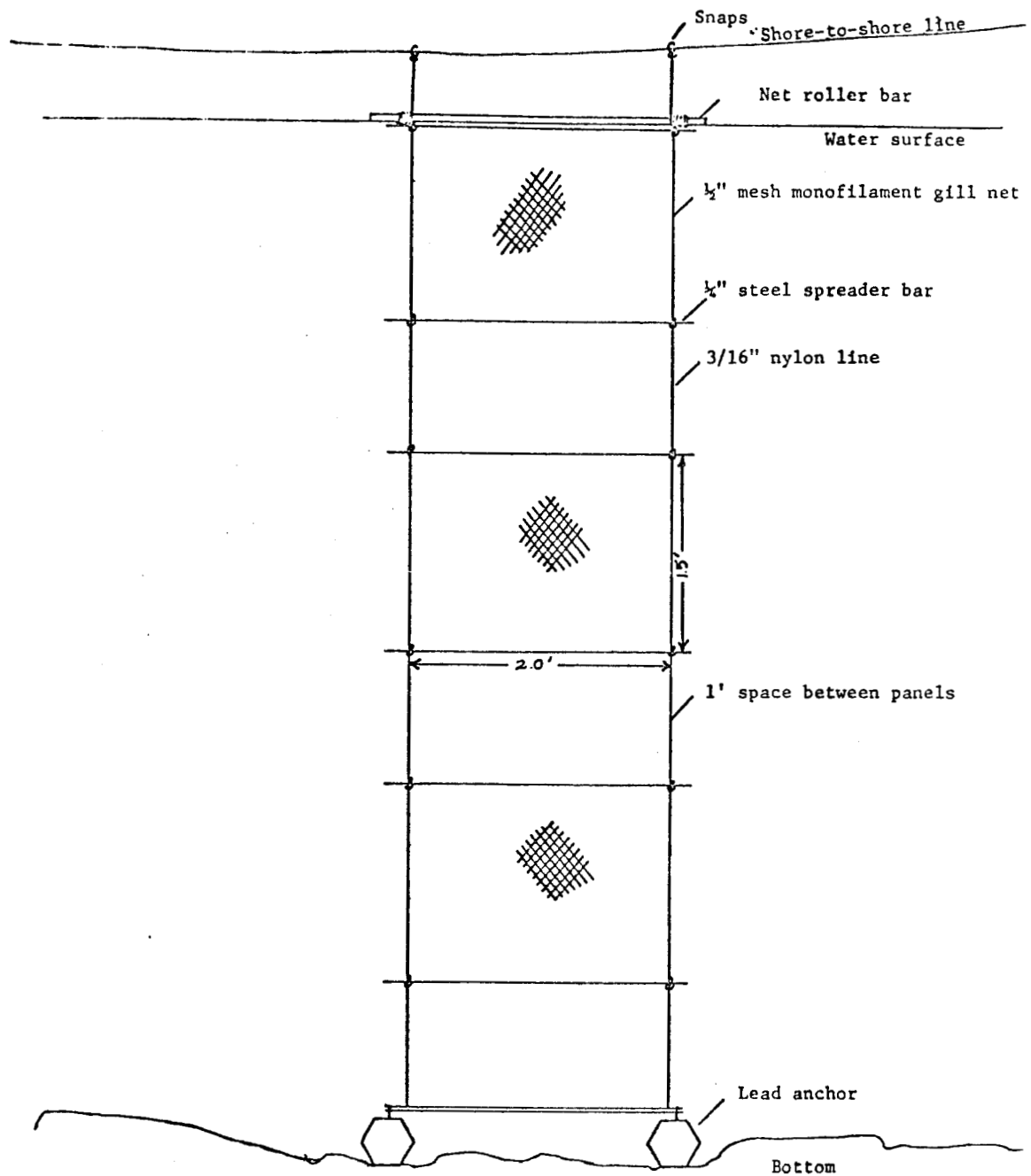


Figure 9. Schematic diagram of smolt gill net arrays used in Kvichak River smolt distribution study, May-June, 1969.

California and in the Bendix sonar testing pool. The first field tests were made in the Kern River in California on 90 mm trout fingerlings which caused a strong response on the counter. The unit then was disassembled and shipped to Bristol Bay.

The 1970 ladder-like transducer mount units were constructed of 8-3/4 inch I.D. plastic pipe primary rails, with 4 inch diameter crossbars or "rungs" which were attached to primary rails by steel hose clamps. The complete unit consists of two sections 11 feet long, 3 feet wide, with a maximum height of 1.7 feet (Figure 10). Alternately mounted on each section, are vertical and lateral scanning transducers. Transducers were mounted 0.8 feet apart. The vertically aimed transducers count smolt in the surface water while those laterally mounted count smolt downstream of the array in the bottom area thus practically eliminating "unscanned" areas (Figures 11 and 12).

The large main rails of the array were sealed into air tight chambers so that the arrays could be either floated by inflation with a scuba tank, or sunk by flooding the chambers with water. One-way valves and hoses provided access to submerged units for water and air.

Due to the weight of electronics and pipe, the smolt arrays were self-positioning under water when attached to an anchored bridle.

Each sonar array was equipped with 200 feet of electronic cable which connected to onshore electronics and printers and 50 feet of hose for introducing either air or water to facilitate array placement.

Features included on the 1970 sonar smolt counter were: (1) a control which compensates for water velocity, (2) a control for water depth, (3) a battery condition meter, and (4) digital printers for upper and lower counts.

As a result of modification of the original one-array sonar counter into a two array system, controls for velocity (to set repetition rate) and the depth (to set range) were limited to a single control for each variable. Consequently, when depth differences existed between arrays, the depth control had to be set at the shallowest array to prevent counting the surface. This in turn prevented the deeper array from sampling the upper stratum of water equal to the depth differences between arrays (Paulus, 1971).

The smolt sonar units were designed to use the same printer as the adult counter. The printers had the capability of printing at 5, 10, or 15 minute intervals. Since counts from vertical and horizontal transducers were separated on the printers, a record of the vertical distribution was produced in addition to total numbers of smolt (Paulus, 1971).

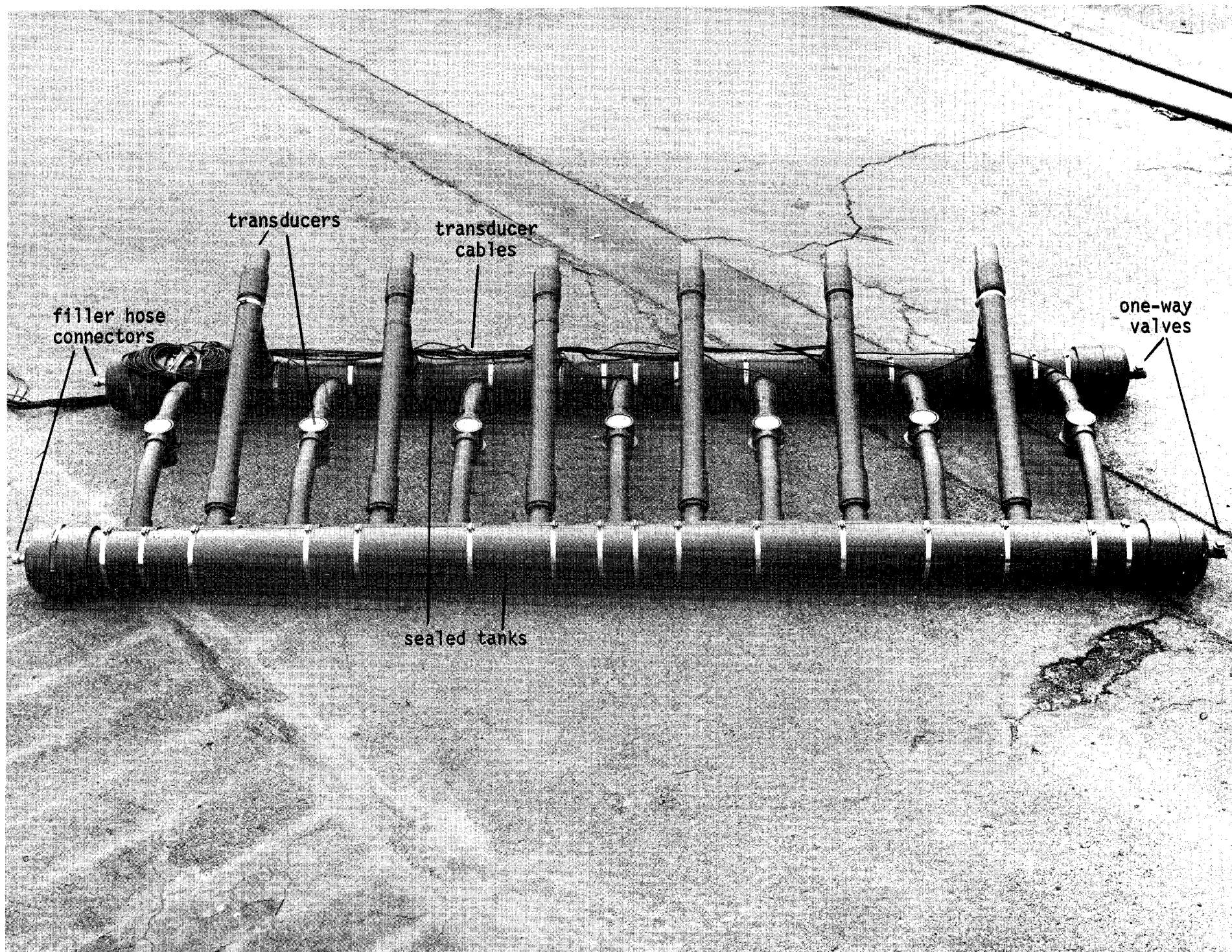


Figure 10. One section of 1970 smolt sonar array.

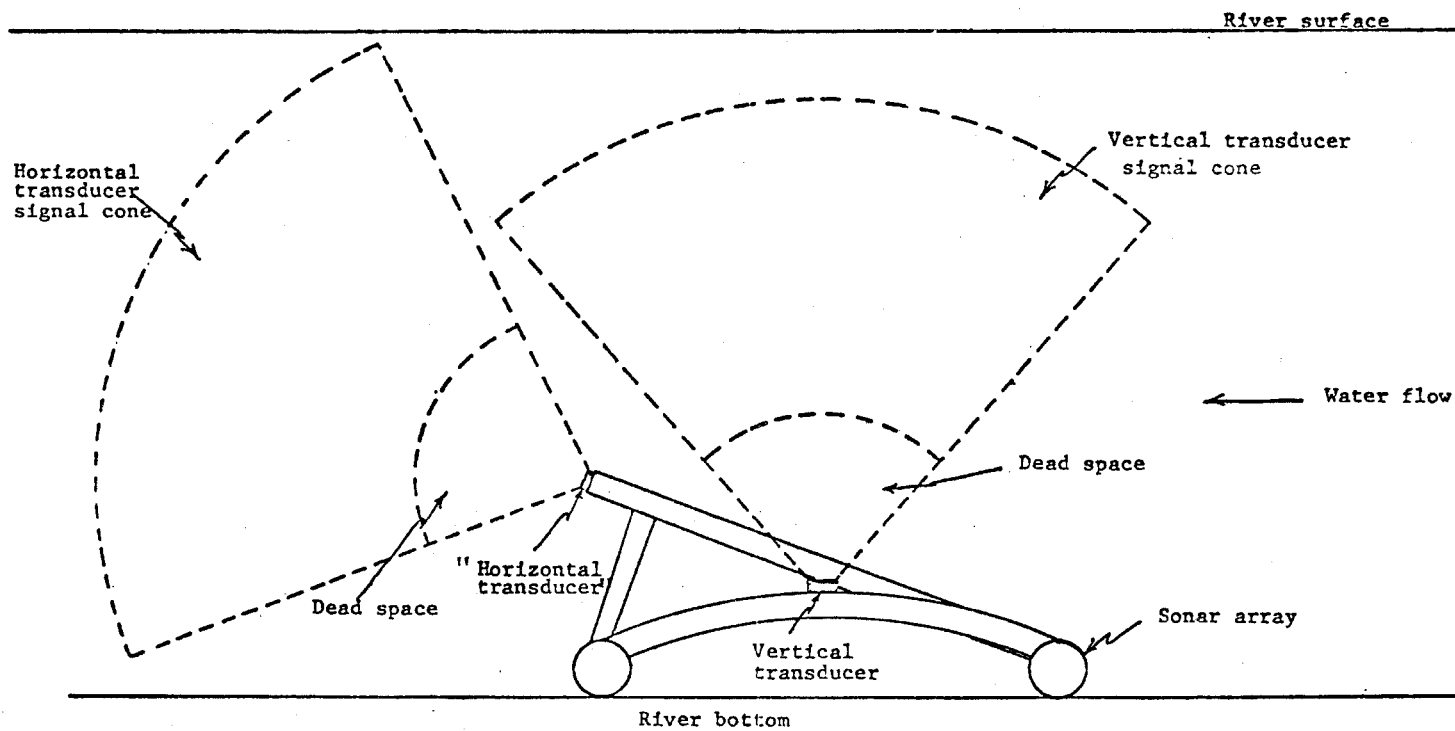


Figure 11. Schematic of the Bendix 1970 smolt counter sonar array, side view, drawing not to scale.

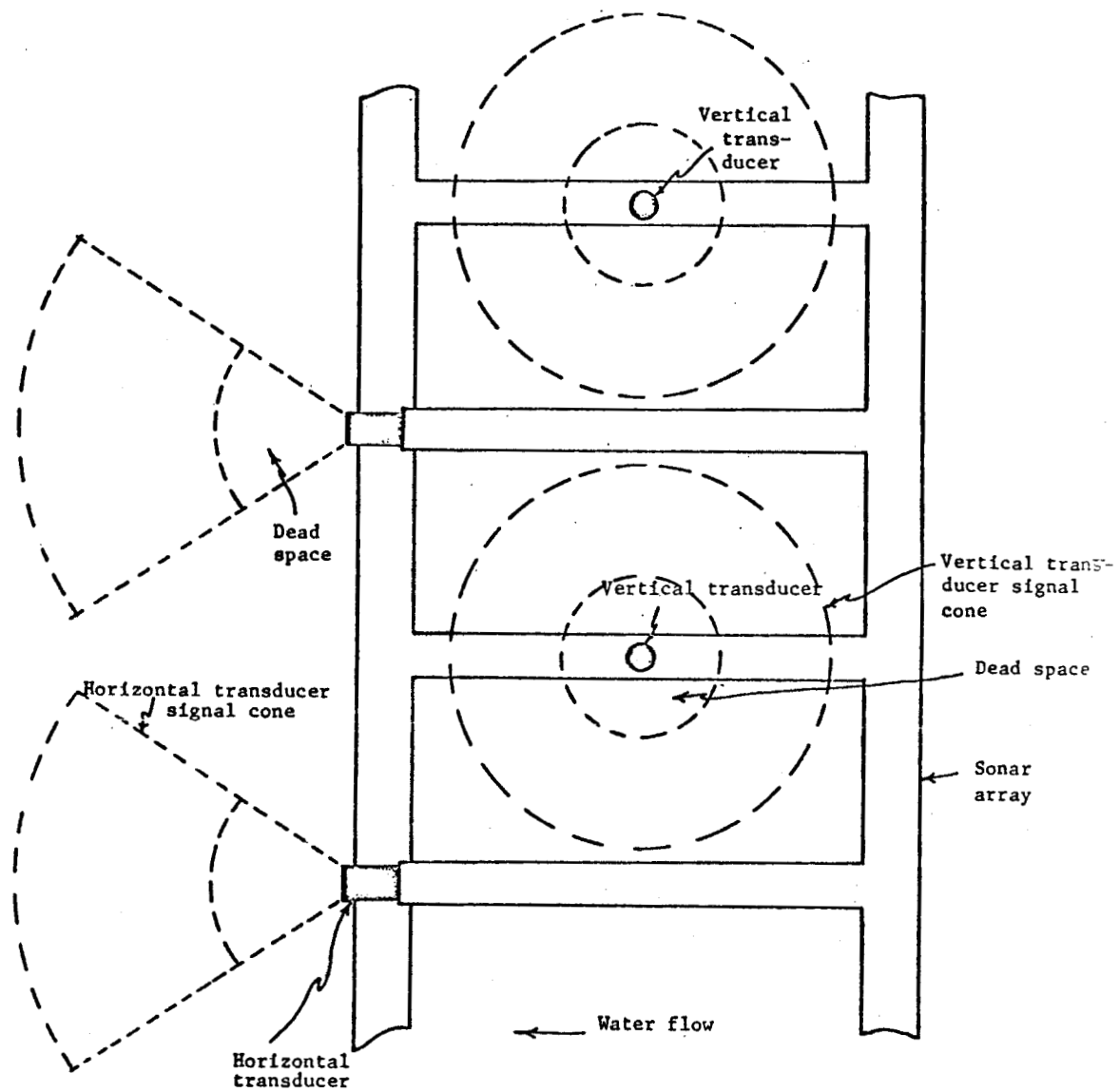


Figure 12. Schematic of the Bendix 1970 smolt counter sonar array, top view, drawing not to scale.

Calibration experiments were immediately begun upon the arrival of the sonar equipment at the Kvichak River. Preliminary efforts to calibrate the sonar unit by placing it in front of a steel fyke trap proved impossible because of sparseness of smolt schools, and surface agitation. A new sonar test site was established offshore from the index net about 80 feet (Figure 2). A 4' x 6' fyke net was set about 8 feet behind the sonar array and 69 calibrations were made. The calibration indicated the theoretical 10 smolt per sonar count was approximately correct, and easily within adjustment range (Paulus and McCurdy, 1972).

The performance of the 1970 sonar counting equipment indicated that with minor modifications, an enumeration of the total smolt outmigration was now possible and would be attempted in 1971 with four sonar array sections spaced across the river.

### 1971 Operation

In 1971 the first total smolt outmigration estimate was achieved utilizing two sonar counting systems. In addition to the existing 1970 sonar model, a new sonar system composed of two 12' arrays was built by the Bendix Corporation.

The 1971 sonar arrays, although similar in principle to its predecessor, incorporated numerous modifications to increase system efficiency. Among these modifications was a design change to lower array profile (Figure 13), in an effort to increase counting efficiency in shallow water. Each of the 1971 arrays held fourteen transducers, seven orientated upwards and seven orientated downstream. Experimentation with downstream transducers gave an optimum angle with the river bottom of  $18^{\circ}$  using transducers with a  $19^{\circ}$  beam width.

Additional modifications were as follows:

1. Transmit pulse - width was reduced from 150 micro-seconds to 120 micro-seconds.
2. The electronics package had improved sensitivity to lower the count threshold.
3. An electronic thermistor circuit with an external probe and panel meter was added to the system to allow continuous monitoring of the water temperature.

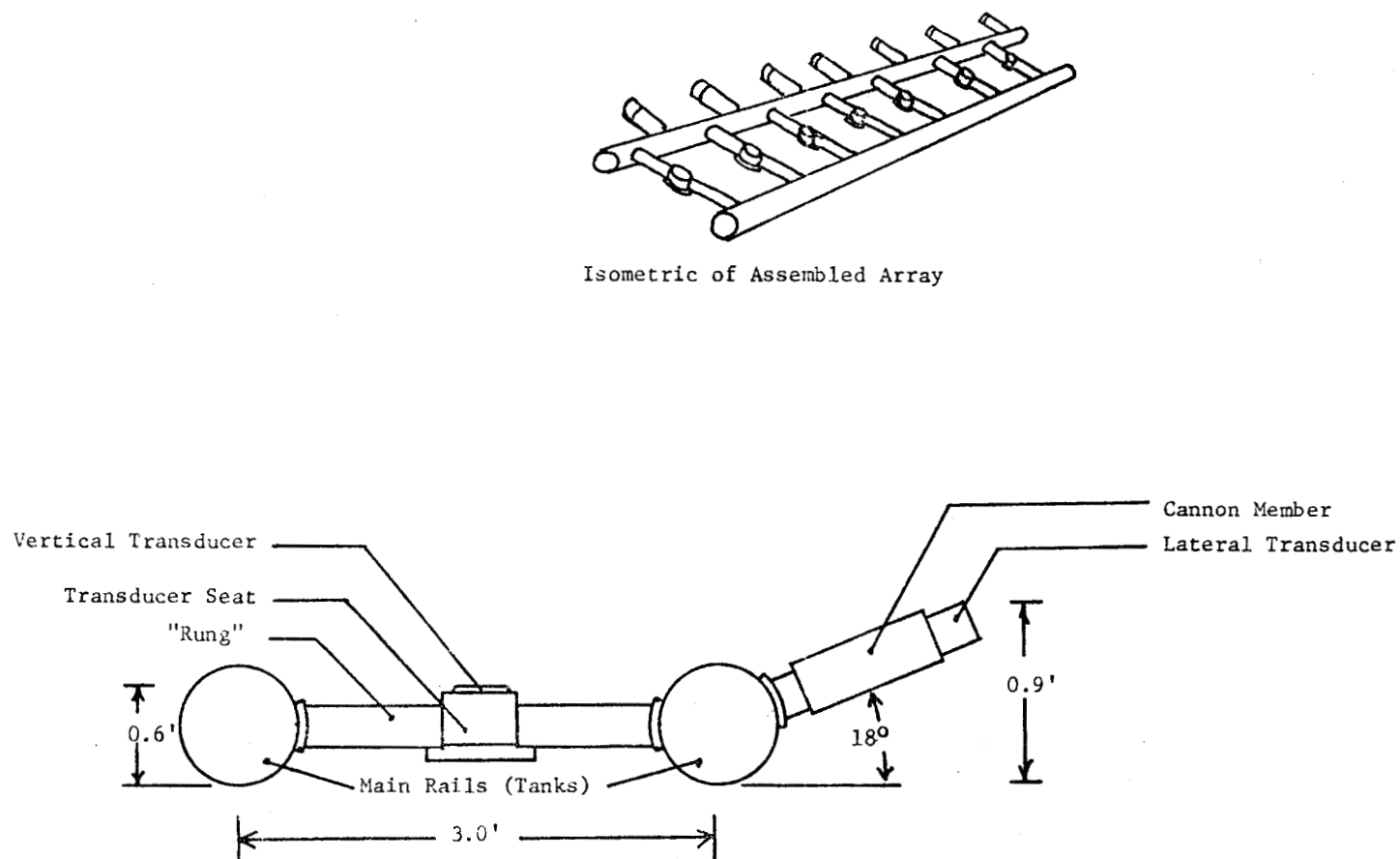


Figure 13. Details of the Bendix smolt sonar transducer arrangement, 1971 model.

4. Modifications were made to allow up to four transducers to be disconnected from the electronics package without influencing the system.
5. In the 1971 model, the downstream transducers counted only in the bottom half of the river and vertical transducers only the upper half, regardless of depth setting; automatic compensations was also made for any beam overlap as the depth setting was readjusted.
6. A new printer and associated electronics were installed which allowed separate printing of upper and lower banks of transducers for each array; corresponding counters were also added.
7. External test points were added to allow circuit monitoring and testing without opening the electronics package.
8. The depth indicator on the 1971 model gave the distance from the river bottom to the range of the sonar beam (the 1970 model gives it from the transducer face).

The 1971 sonar site was located 4 miles downstream from the ADF&G field station (Figure 2). At this location the Kvichak River is confined to a single main channel with a relatively small secondary channel passing off to the west side. The main channel, 640 feet wide, possesses a relatively smooth even bottom averaging 4-1/2 feet deep.

Water velocity information was collected at the sonar site during the field season to relate smolt passage rates to current velocities. Measurements were taken at 40 foot intervals across the river and at 1 foot vertical intervals with a Gurly type AA current meter (Russell, 1972).

Sonar system calibration in 1971 was conducted using standard 6' x 4' fyke nets with wings positioned behind the sonar arrays as in 1970. Calibrations were first made for the 1971 sonar gear and later in the season for the 1970 sonar gear. Actual calibration was accomplished by determining the number of smolt captured per sonar count. This was done by first assessing the number of smolt in a fyke net catch. Due to the large numbers characteristic of catches, a 1 pound subsample would be extracted and counted. The resulting smolt per pound would then be multiplied by the catch weight producing an estimate of the number in the catch. Next, this calculated number of smolt in the catch would be divided by the corresponding sonar counts accumulated during the calibration period. The calibration periods varied depending upon the smolt passage rates encountered. High passage rates

would limit calibration period to a few minutes to keep the catch weight down so it could be handled.

To determine which calibrations would be utilized, the designing engineers' specifications were considered. These include: (1) that at optimal adjustment the sonar would register one count for 10 smolt of a specific biomass, (2) that it was mechanically impossible that less than five fish could trigger a count, and (3) that no more than 20 smolt could cross the unit with only a single count registered. From these specifications it was established that calibrations of under five fish per count or over 20 fish per count could be discounted as mechanically invalid. The reasonableness of these limits can be realized when the placement of the net 10 feet behind the sonar array is considered. In that distance schools moving laterally can miss the sonar and be caught in the net or counted and not caught. Consequently, the 5 to 20 fish per count was adapted as the acceptable limits for valid calibrations.

After the season, evidence of optimal sampling conditions was sought from day-night and high-low passage rate calibration data. The calculated smolt per count for each group was then averaged and expanded by 12/9 to compensate for width differences between sonar arrays and calibrating fyke net. This process was repeated for both sonar systems. A calculation was also made for under-counting or over-counting from the measured velocity of each array and the velocity set on the electronics; the counts were appropriately adjusted.

The results from sonar calibration indicated that the 1970 sonar equipment was counting at 247.9 smolt per sonar count (Parker, in press). The observed low counting efficiency was attributed to obvious shipping damage that occurred while the gear was in transit from Los Angeles in the spring of 1971. The 1971 sonar equipment exhibited calibrations close to designed electronic capabilities with an observed 9.96 smolt per sonar count (Parker, in press).

To insure proper recording and labeling of valid sonar counts, instruments were continually monitored. It was noted that winds over 40 m.p.h. and heavy precipitation would entrap air into the river and cause false counts. Likewise, ice acts as a strong target and the range must be set below the depth of the ice to prevent invalid counts.

As in index operations, sonar sampling "days" were on a noon to noon basis. To facilitate this, the digital counters were logged, cleared and set to "0" at 6 hour intervals beginning at 12 noon. This prevented any error buildup in the timers that trigger interval printing. In that the sonar arrays

sample only that portion of the river channel directly over them, it is necessary to expand the observed counts to compensate for the unsonified portion of the river channel between arrays and between arrays and shore. The procedure for sonar count expansion to estimate total outmigration is as follows:

1. The season total sonar counts for each array is determined.
2. Sonar counts are transposed into numbers of smolt by applying the appropriated calibration and current velocity correction factors.
3. The number of smolt per foot of array is computed for each sonar array fished.

$$\frac{\text{Total smolt over array}}{\text{Array length 12'}}$$

4. The distances between array centers and inshore arrays and river banks are assessed.
5. The number of smolt per foot of sonar array is multiplied by one half of the distances to adjacent array centers.
6. The number of smolt between an inshore array and its adjacent river bank is calculated by multiplying the number of smolt per foot of the inshore array by half the distance to its bank.
7. The total outmigration estimate is derived by summing the calculated number between array centers plus the calculated number of smolt between inshore array centers and the adjacent river banks.

The 1971 total outmigration was estimated at 91,682,813 sockeye salmon smolt. This estimate when compared to the smolt index (1,927,984) indicated a ratio of 47.6 total outmigrants per indexed smolt. Comparison of the daily outmigration levels as measured at sonar and index reflected similar peak migration periods; however, sonar recorded several minor peaks which were not evident from the index data (Figure 14).

#### 1972 Operation

In 1972 three sonar counting systems were utilized for smolt enumeration in the Kvichak River. The 1970 and 1971 models previously described

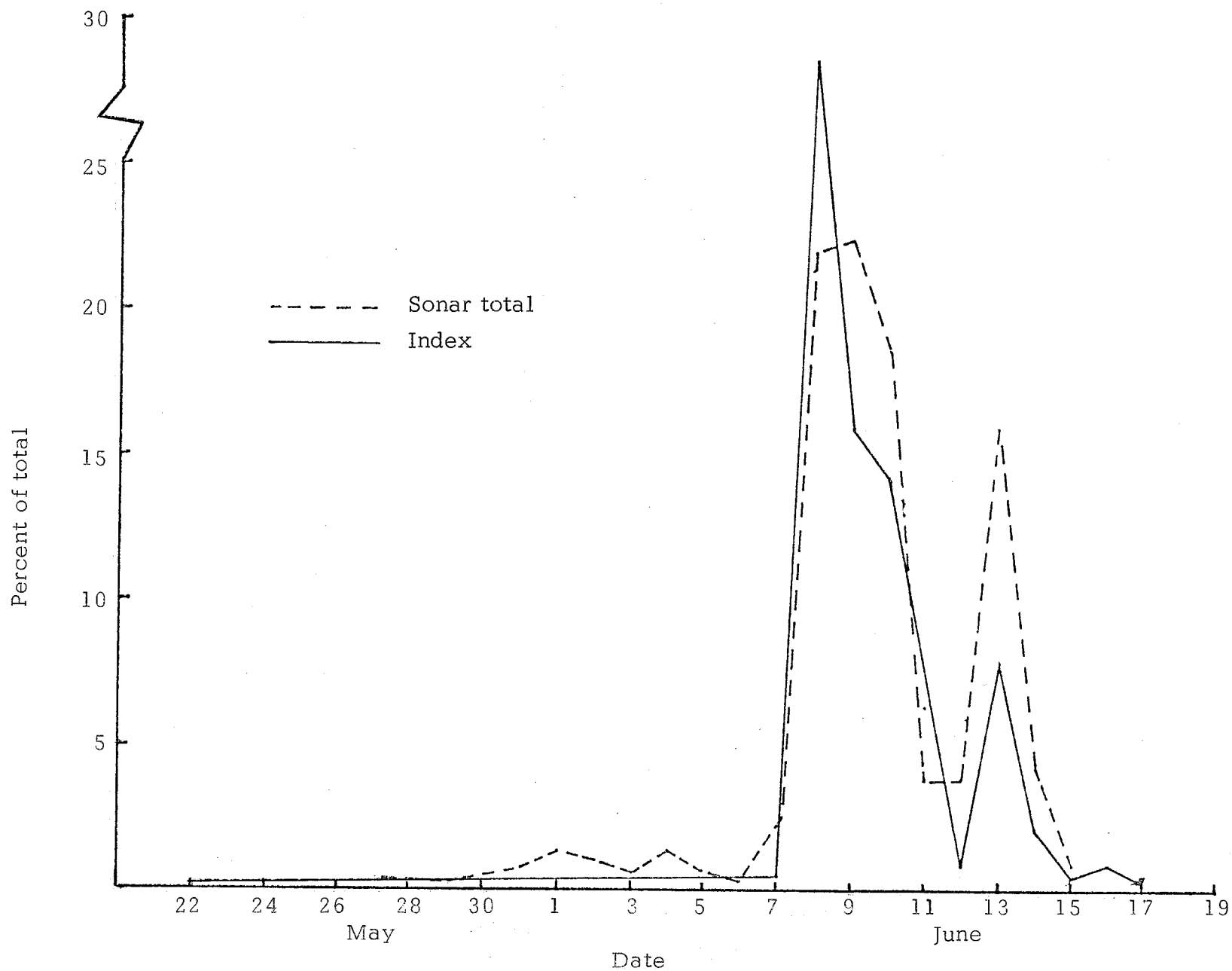


Figure 14. Percent of total outmigration by day as measured at index and sonar, 1971.

and a more sophisticated 1972 model fitted with 300 foot cable allowing more latitude in placement within the river channel. The electronic package of the 1972 model was the same as 1971, but modified to include light emitting diodes (L.E.D.'s) which light when a return echo is received from a specific transducer. The L.E.D.'s were incorporated into the new system to aid in identification of problem transducers and investigate school patterns (Figure 15). The external test points were increased to include one to monitor each bank of transducers and each key circuit in the electronic package. An electronic alarm was also provided as a plug-in option to alert crew when smolt counts are occurring.

Two oscilloscopes were used with the sonar systems in 1972 to monitor school depth, thickness and orientation within the channel during day and night outmigrations.

The sonar enumeration site remained unchanged from 1971 (Figure 2). As a result of increased cable length on the 1972 sonar arrays, the fishing stations were spaced more uniformly across the river channel.

Due to limited manpower, it was not possible to monitor the 1970 sonar equipment on the east bank. It was the least important gear since this equipment was in an area of few smolt and continuous deep ice. Since it was not monitored constantly, the data was not used for outmigration estimation.

Water velocity measurements were taken periodically throughout the season for adjusting the velocity setting on the sonar electronics. The velocity setting regulates the repetition rate of the sonar signals so each group of fish is "sounded" only once.

Sonar calibration techniques and sonar operating procedures remained identical to the 1971 program. Calibration efforts in 1972 were limited to assessing variability of the 1972 sonar electronics. Results indicated the unit was functioning at designed capability with an observed 11.81 smolt per sonar count (Parker, 1974). Calibration factors for the 1971 sonar equipment remained unchanged from 1971.

Expansion techniques remained unchanged from the described for 1971, although distances between array centers were changed. Since the ice run out was continuous throughout the duration of the smolt outmigration, data gathering required almost constant observation of the river and ice conditions. During the daylight hours the smolt traveled below the depth to which the ice reached, so the range of the sonar was pulled in to miss the ice. At night, when smolt were at the surface, the range needed to be set within 1/10 foot of the surface, and became susceptible to ice counting. Visual observations were required to clear ice "counts" from the equipment. Observations on the light bank on the 1972 equipment, and on the oscilloscope gave information on

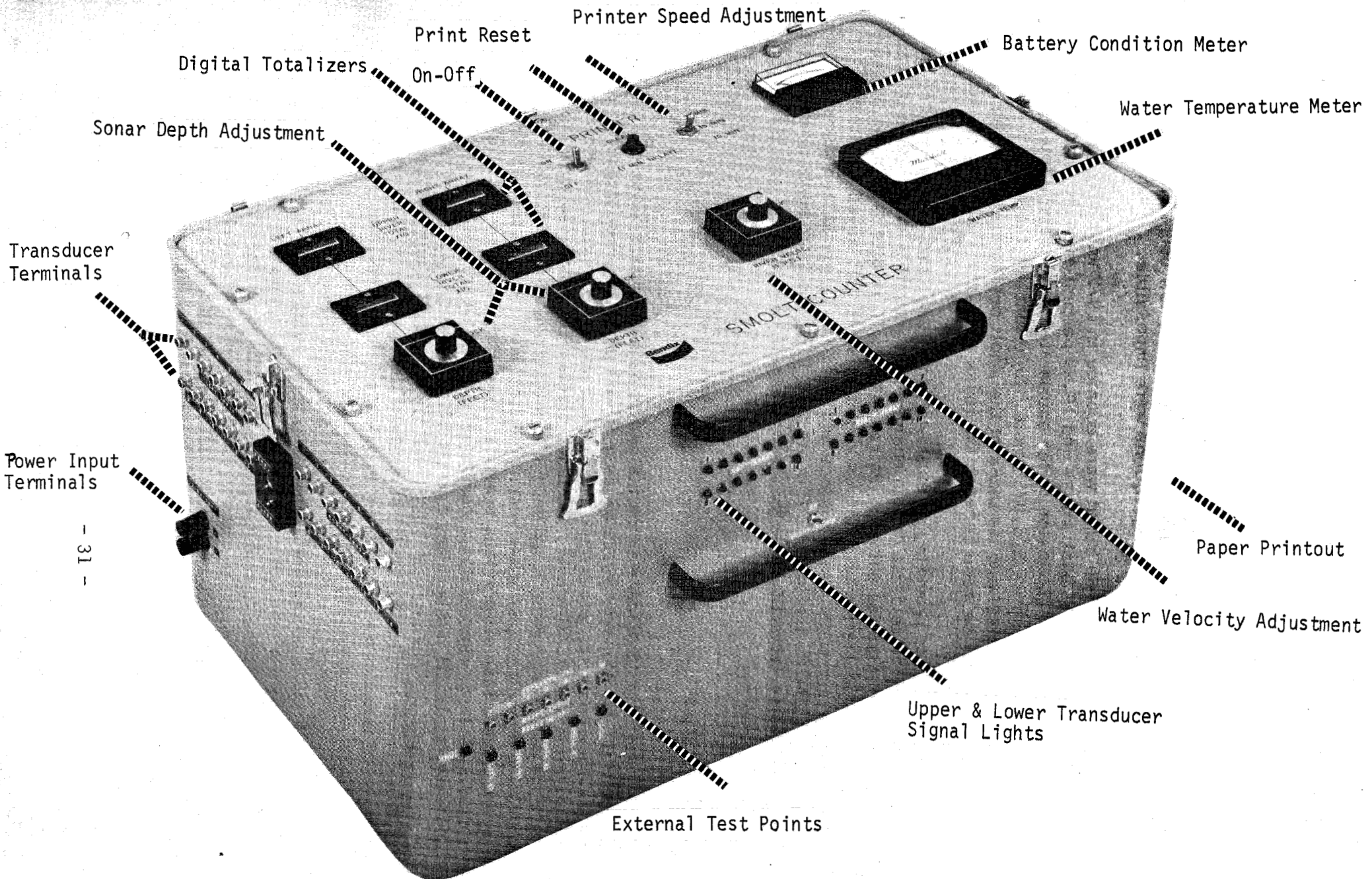


Figure 15. 1972 sonar smolt counter with depth and velocity controls, left and right upper and lower digit counters, transducer signal lights, and column printer.

target depth, strength, and spatial distribution which could be relied upon heavily to separate smolt from ice counts during the few hours on unusually dark nights when visual ice observations were impossible.

A total of 6,649,760 smolt were counted in 1972 with 80.7 percent enumerated over the west bank arrays and 19.29 percent over the east bank arrays (Parker, 1974). Expansion of the enumerated smolt gave a total season outmigration estimate of 67,575,075 smolt. Unfortunately the index program was prevented from obtaining its index of the smolt outmigration; consequently, no comparison could be made between the index and sonar outmigration estimate.

In addition to providing an estimate of the total smolt outmigration, the sonar counter by virtue of its design enabled a quantitative examination of smolt vertical diurnal migration patterns (Parker, 1974). This was facilitated by the sonar systems separation of counts recorded by vertically aimed transducers which sample mid-water to the surface and horizontally aimed transducers which sample mid-water to the bottom. Counts from 1971 and 1972 sonar enumeration are presented in Appendix Table 9.

## CONCLUSIONS

The index program was maintained through the years of the total smolt enumeration development years because it was providing data similar to that of previous years for forecasting the Kvichak sockeye returns and setting escapement levels. However, the index program is considered unreliable because of the improbability of getting identical net efficiency, with representative sampling, year after year. The field work in the years 1970 through 1972 did more than all previous seasons to quantify problems with the fyke net indexing method. Recent data, combined with past published information, indicates that: (1) numbers and age classes of smolt may be unevenly distributed across the channel; (2) 3 hour indices contain a highly variable portion of daily smolt outmigrations; (3) significant time periods may be unfishable due to ice interference; and (4) net avoidance is not a constant, but varied with light, velocity, turbidity, net color and other factors.

With the development of the sonar total outmigration estimate program, it is hoped that the fyke net catches will eventually prove to be a rather constant proportion of the total outmigration in order to utilize historical data. Such a relationship might permit the estimation of total outmigrations from past season indexes. The index program will continue in 1973 and 1974 for this purpose. Such estimates will need to be utilized carefully and clearly qualified as to reliability.

The smolt sonar gear is highly sophisticated, "state of the art" equipment designed specifically for counting smolt. In 3 years of testing, only one system malfunctioned seriously, and that was probably due to shipping from California, which also caused damage to the case. The electronics must be kept dry and handled with care, but are not affected by temperature extremes. They will operate for 2 to 3 months on a standard 12-volt battery, since a sonar system power drain is much less than that of a flashlight with two "D" cells. Stability of the calibrations and electronics testing indicate no change in the equipment ability to count in three seasons of use.

Underwater sonar arrays are engineered so they float high when filled with air to make cleaning and servicing easy. When filled with water and bridled to an anchor, they stay in position on the river bottom. When painted an olive drab color, the gear is nearly invisible to the human eye and causes no detectable change in smolt distribution. The gear can be fished in water from 5 to 10 feet deep at a velocity range of 0 to 12 feet per second.

In that the sonar equipment has successfully provided total outmigration estimates for 1971 and 1972 under extremely rigorous conditions, the sonar equipment will continue to be relied upon as primary sampling gear. However, additional consideration needs to be given to: (1) an alternative fishing site where the channel is narrower and deeper, allowing a higher ratio of sampled to unsampled area with the same amount of gear; (2) system testing for all sonar functions before river installation to eliminate or reduce the need for fyke net calibrations; and (3) new installation technology which will permit a three man crew to carry out placement, inspection, and servicing.

## LITERATURE CITED

- Burgner, Robert L., Charles J. DiCostanzo, Robert J. Ellis, George Y. Harry, Jr., Wilbur L. Hartman, Orra E. Kerns, Jr., Ole A. Mathisen, and William F. Royce. 1969. Biological studies and estimates of optimum escapements of sockeye salmon in the major river systems in South-western Alaska. U.S. Fish Wildl. Serv.
- Church, W. 1963. Red Salmon Smolts, Kvichak River System, 1961. Informational Leaflet No. 31, Alaska Department of Fish and Game.
- Foerster, R.E. 1968. The Sockeye Salmon (Oncorhynchus nerka). Fisheries Research Board of Canada, Ottawa.
- Kerns, O.E. 1961. Abundance and Age of Kvichak River Red Salmon Smolts. U.S. Fish & Wildl. Serv., Bur. of Comm. Fish. Bull. 61 (189).
- Kerns, Orra E. Jr., T.S.Y. Koo, 2nd, C.O. Junge, Jr. 1961. Summary report on photo-electric counting of red salmon smolts, 1960. University of Wash., Fish. Res. Inst. Circ. 141.
- Kerns, Orra E., and R.A. Marriott. 1963. Kvichak River Enumeration of Red Salmon Smolt Migration, 1962. Alaska Department of Fish and Game, Informational Leaflet 25.
- Marriott, R.A. 1965. Kvichak River Red Salmon Smolt Studies. Alaska Department of Fish and Game, Informational Leaflet 48.
- Mathisen, Ole A., and O.E. Kerns, Jr. 1964. Abundance, distribution, and size of juvenile red salmon of the 1960 year class in Iliamna Lake, Alaska, Pg. 191-202. In George Dahlgren (ed.), Proc. 14th Alaskan Sci. Conf., Alaska Div., Amer. Assoc. Advance. Sci.
- McCurdy, Michael and Robert Paulus. 1972. 1969 Kvichak River Sockeye Salmon Smolt Studies. In 1969 Bristol Bay Sockeye Salmon Smolt Studies (Ed. Michael McCurdy). Alaska Department of Fish and Game Tech. Data Rpt. 3.
- Paulus, Robert and Michael McCurdy. 1968. Kvichak River Smolt Study. U.S. Bur. of Comm. Fish. Quart. Prog. Rpt. July 1-Sept. 30, 1968. Proj. No. 5-5-R-3.
- Paulus, Robert and Michael McCurdy. 1972. 1970 Kvichak River Sockeye Salmon Smolt Studies. In 1970 Bristol Bay Sockeye Salmon Smolt Studies (Ed. Phillip Russell). Alaska Dept. Fish and Game Tech. Data Rpt. 4.

#### LITERATURE CITED (cont.)

- Paulus, Robert and Michael McCurdy. 1969. 1968 Kvichak River Sockeye Salmon (Oncorhynchus nerka) Smolt Studies. In 1968 Bristol Bay Sockeye Salmon Smolt Studies. (Ed. Michael McCurdy). Alaska Dept. Fish and Game, Informational Leaflet 138.
- Paulus, Robert. 1971. Kvichak River Sockeye Salmon (Oncorhynchus nerka) Smolt Studies. U.S. Bur. of Comm. Fish., Ann. Tech. Rep. 1970 Proj. No. AFC-21-1.
- Pennoyer, Steven. 1966. 1965 Kvichak River Red Salmon (Oncorhynchus nerka) Smolt Studies. Alaska Dept. Fish and Game, Informational Leaflet 83.
- Pennoyer, Steven and Donald Stewart. 1969. 1967 Kvichak River Red Salmon (Oncorhynchus nerka) Smolt Studies. In 1967 Bristol Bay Red Salmon Smolt Studies (Ed. Donald Stewart). Alaska Department of Fish and Game, Informational Leaflet 134.
- Pennoyer, Steven and Melvin Seibel. 1965. 1964 Kvichak River Red Salmon (Oncorhynchus nerka) Smolt Studies. Alaska Department of Fish and Game, Informational Leaflet 58.
- Pennoyer, Steven and Donald Stewart. 1967. 1966 Kvichak River Red Salmon (Oncorhynchus nerka) Smolt Studies. In 1966 Bristol Bay Red Salmon Smolt Studies. (Ed. Donald Stewart). Alaska Department of Fish and Game, Informational Leaflet 102.
- Russell, Philip A. 1972. 1971 Kvichak River Sockeye Salmon Smolt Studies. In 1971 Bristol Bay Sockeye Salmon Smolt Studies. (Ed. Phillip Russell and Michael McCurdy). Alaska Department of Fish and Game Tech. Data Rpt. 2.

APPENDIX HISTORICAL TABLES (SMOLT)

Appendix Table 1. Kvichak River 24-hour sockeye salmon smolt index catches, average lengths and weights, 1955-1972.

Age I

Age II

Outmigration	Number	Percent <sup>2/</sup>	Average length	Weight	Number	Percent <sup>2/</sup>	Average length	Weight	Total number	Total 24-hr. index <sup>1/</sup>
1955	18,198	7	89 mm	-	241,780	93	109 mm	-	( 259,978) <sup>3/</sup>	7.8
1956	30,287	39	92 mm	-	47,373	61	116 mm	-	( 77,660) <sup>3/</sup>	2.3
1957	22,287	72	96 mm	7.3 g	8,654	28	120 mm	14.4 g	30,907	0.9
1958	3,267,274	98	84 mm	4.6 g	66,679	2	114 mm	-	3,333,953	100.0
1959	85,916	3	80 mm	-	2,777,960	97	99 mm	7.6 g	(2,863,876) <sup>3/</sup>	85.9
1960	61,400	10	91 mm	6.3 g	552,603	90	108 mm	10.3 g	( 614,003) <sup>4/</sup>	18.4
1961	26,038	72	92 mm	6.8 g	10,126	28	117 mm	13.1 g	( 36,164) <sup>3/</sup>	1.1
1962	1,130,820	94	82 mm	4.3 g	72,180	6	110 mm	9.9 g	1,203,000	36.1
1963	113,338	3	83 mm	4.8 g	4,116,093	97	98 mm	7.5 g	4,229,431	126.9
1964	458,122	22	87 mm	5.2 g	1,603,464	78	108 mm	9.8 g	2,061,586	61.8
1965	64,377	4	90 mm	6.8 g	1,748,178	97	109 mm	11.3 g	1,812,555	54.4
1966	252,384	92	94 mm	7.4 g	23,377	8	114 mm	12.6 g	275,761	8.3
1967	2,866,214	93	86 mm	5.9 g	222,528	7	118 mm	14.2 g	3,088,742	92.6
1968	648,321	11	88 mm	5.5 g	5,475,362	89	104 mm	9.2 g	6,123,683	183.6
1969	594,327	52	92 mm	5.7 g	541,017	48	109 mm	10.6 g	1,135,344	34.0
1970	185,356	38	91 mm	6.0 g	298,882	62	110 mm	11.0 g	483,638	14.5
1971	1,803,040	94	90 mm	5.8 g	124,944	6	111 mm	11.1 g	1,927,984	57.8
1972	11,937 <sup>5/</sup>	1	80 mm	-	1,409,167 <sup>5/</sup>	99	106 mm	10.0 g	1,421,104 <sup>5/</sup>	42.6
Eighteen-year average.										
	646,646	45	88 mm	5.9 g	1,074,465	55	110 mm	10.8 g	1,721,076	51.6

<sup>1/</sup> One index point = 33,340 smolt.<sup>2/</sup> Numbers of Age I and Age II fish derived from rounded-off season percentages except in 1963, 1964, 1965 and 1966 when rounded percentages were derived from numbers of smolts obtained by weighting length frequency distribution by daily catches.<sup>3/</sup> 24-hour index catch estimated by ratios with years of actual 24-hour fishing and from visual observations of smolt migration outside the 3-hour index period.<sup>4/</sup> 24-hour index catch estimated from ratios with the 3-hour index period catch obtained during only 2 days of actual 24-hour fishing.<sup>5/</sup> Estimated from ratio of 1971 index to 1971 total outmigration applied to 1972 total outmigration.

Appendix Table 2. Percent of sockeye salmon smolt outmigration occurring during index hours (2200-0100), Kvichak River, 1955-1972.

Year	Outmigration <sup>1/</sup>	Percent outmigration during index hours (2200-0100)
1955	259,978	82.3%
1956	77,660	82.3
1957	30,907	82.3
1958	3,333,953	57.4
1959	2,863,876	57.4
1960	614,003	74.1
1961	36,164	82.3
1962	1,203,000	25.1
1963	4,229,431	32.6
1964	2,061,586	38.3
1965	1,812,555	46.9
1966	275,761	39.5 <sup>2/</sup>
1967	3,088,742	30.1
1968	2,295,023	37.5
1969	543,351	47.9
1970	218,951	45.3
1971	212,328	11.0
1972	-	-
Averages	1,362,192	51.3 <sup>3/</sup>

<sup>1/</sup> The methods used to expand the 3-hour index catches to 24-hour catches for the years 1955, 1956, 1959, 1960, and 1961 are explained in the 1964 smolt report.

<sup>2/</sup> This figure is nearly meaningless since ice flow precluded any estimate of comparative migration by period.

<sup>3/</sup> Note that the average 51.3% migration during the index hours is probably high as the percent for three of the four years showing 82.3% was assumed on the basis that 82.3% of the smolt in 1957 migrated during the index hours. Sampling was not on a 24-hour basis for the years, 1955, 1956, 1959, 1960 and 1961.

Appendix Table 3. Kvichak River 3-hour sockeye salmon smolt catches, 1955-1969, (3-hour index catches).

Year of outmigration	Age I		Age II		Total number	Total 3-hr. index <sup>1/</sup>
	Number	Percent	Number	Percent		
1955	14,971	7	198,897	93	213,868	6.4
1956	24,916	39	38,970	61	63,886	1.9
1957	18,306	72	7,119	28	25,425	0.8
1958	1,874,512	98	38,255	2	1,912,767	57.4
1959	49,292	3	1,593,781	97	1,643,073	49.3
1960	45,478	10	409,305	90	454,783	13.6
1961	21,420	72	8,330	28	29,750	0.9
1962	283,328	94	18,085	6	301,413	9.0
1963	41,424	3	1,339,379	97	1,380,803	41.4
1964	173,919	22	616,623	78	790,542	23.7
1965	34,009	4	816,212	96	850,221	25.5
1966	100,199	92	8,713	8	108,912	3.3
1967	864,650	93	65,081	7	929,731	27.9
1968	252,452	11	2,042,571	89	2,295,023	68.8
1969	282,542	52	260,809	48	543,351	16.3
1970	83,201	38	135,750	62	218,951	6.6
1971	198,527	94	13,801	6	212,328	6.4
1972	-	1	-	99	-	-
Seventeen-yr. average	256,656	45	447,746	55	704,402	21.1

<sup>1/</sup> One index point = 33,340 smolt.

Appendix Table 4. Parent escapement and corresponding sockeye salmon smolt production, Kvichak River, 1952-1970.

Year of spawning	Escapement in thousands	24-hour index smolt produced			24-hour index smolt per spawner x 10 <sup>3</sup>		
		Age I	Age II	Total	Age I	Age II	Total
1952	5,970		241,780			40	
1953	321	18,198	47,373	65,571	57	148	205
1954	241	30,287	8,654	38,941	126	36	162
1955	250	22,253	66,679	88,932	89	267	356
1956	9,443	3,267,274	2,777,960	6,045,234	346	294	640
1957	2,964	85,916	552,603	638,519	29	186	215
1958	535	61,400	10,126	71,526	115	19	134
1959	680	26,038	72,180	98,218	38	106	144
1960	14,630	1,130,820	4,116,093	5,246,913	77	281	358
1961	3,706	113,338	1,603,464	1,716,802	30	433	463
1962	2,581	458,122	1,748,178	2,206,300	178	677	855
1963	339	64,377	24,818	89,195	190	73	263
1964	957	252,384	222,528	474,912	264	233	497
1965	24,326	2,866,214	5,475,362	8,341,576	118	225	343
1966	3,775	648,321	541,017	1,189,338	172	143	315
1967	3,216	594,327	298,882	892,609	185	93	278
1968	2,557	185,356	124,944	310,300	72	49	121
1969	8,394	1,803,040	1,409,167	3,212,207	215	168	383
1970	13,935	11,937			.9		
1971	2,387						
Averages	4,478	683,980	1,074,545	1,758,525	149	203	361

Appendix Table 5. Dates of sampling and peak periods of sockeye salmon smolt outmigration, Kvichak River, 1955 - 1972.

Year	Date	Number of days	Date	Number of days	Percent of total catch
1955	5/28-6/27	31	6/4-9	6	94%
1956	5/24-7/4	42	6/1-9, 14-16	12	88
1957	5/28-7/24	58	5/28-6/6	10	84
1958	5/10-7/5	56	5/22-6/3	13	80
1959	5/23-6/28	36	5/26-6/2	8	98
1960	5/18-6/19	33	5/28-6/4	8	80
1961	5/23-6/20	29	5/23-6/2	11	81
1962	5/27-7/4	39	6/2-15	14	88
1963	5/16-6/16	32	5/24-29, 6/7-9	9	86
1964	5/19-6/22	35	6/4-12	9	84
1965	5/17-6/14	28	5/24-30	6	91
1966	5/18-6/17	31	6/4-11	8	97
1967	5/17-6/17	31	5/26-6/6	12	80
1968	5/17-6/14	28	5/24-27, 6/1-5	9	76
1969	5/23-6/18	26	5/27-6/5, 6/15	14	97
1970	5/1-6/15	46	5/25-29, 6/2-4	8	65
1971	5/22-6/19	28	6/9-13, 6/14-17	9	99
1972	-	-	6/9-18 <sup>1/</sup>	9 <sup>1/</sup>	83 <sup>2/</sup>
Averages		35		10	86

<sup>1/</sup> Period estimated from 1972 outmigration results.

<sup>2/</sup> Percentage taken from 1972 outmigration results.

Appendix Table 6. Parent escapement and corresponding percent of Age II sockeye salmon smolt produced, 1952-1969.

Year	Escapement	Percent Age II smolt produced <sup>1/</sup>
1952	5,970,000	10 - 15% <sup>2/</sup>
1953	321,000	72%
1954	241,000	22%
1955	250,546	75%
1956	9,443,318	46%
1957	2,842,810	87%
1958	534,785	14%
1959	680,000	73%
1960	14,630,000	78%
1961	3,705,849	93%
1962	2,580,884	79%
1963	338,760	27%
1964	957,120	47%
1965	24,325,926	66%
1966	3,775,184	45%
1967	3,216,208	33%
1968	2,557,440	40%
1969	8,394,204	44%

<sup>1/</sup> Based on 24-hour index catches.

<sup>2/</sup> Estimated on basis of 2-ocean returns in 1956 and 5<sub>2</sub> fish in 1957 vs. 5<sub>3</sub> fish in 1957 and 6<sub>3</sub> fish in 1958.

Appendix Table 7. Parent sockeye salmon escapement and corresponding adult return per indexed smolt, by age group, Kvichak River, 1952-1965.

Brood year	Age I smolt				Age II smolt		
	Escapement <sup>1/</sup>	Index <sup>1/</sup>	Adult return <sup>1/</sup>	Ret./smolt	Index <sup>1/</sup>	Adult return <sup>1/</sup>	Ret./smolt
1952	5,970	--	15,906	--	242	3,587	14,82
1953	321	18	128	7.11	47	407	8.66
1954	241	30	104	3.47	9	634	70.44
1955	251	22	344	15.64	67	1,418	21.16
1956	9,443	3,267	30,108	9.22	2,778	7,469	2.69
1957	2,843	86	487	5.56	553	3,446	6.23
1958	535	61	119	1.95	10	157	15.70
1959	680	26	311	11.96	72	214	2.97
1960	14,630	1,131	1,816	1.61	4,116	51,965	12.63
1961	3,706	113	502	4.44	1,603	2,888	1.80
1962	2,581	458	238	0.52	1,748	4,986	2.85
1963	339	64	92	1.44	23	979	39.16
1964	957	252	2,348	9.32	223	2,965	13.30
1965	24,326	2,866	9,748	3.40	5,475	32,917	6.01

<sup>1/</sup> In Thousands

Appendix Table 8. Kvichak River sockeye salmon smolt indices and corresponding adult return per indexed smolt, 1952-1965.

Brood Year	Total Smolt		Ret./smolt
	Index <sup>1/</sup>	Adult Return <sup>1/</sup>	
1952			
1953	65	535	8.23
1954	39	738	18.92
1955	89	1,762	19.80
1956	6,045	37,577	6.22
1957	639	3,933	6.16
1958	71	276	3.89
1959	98	525	5.36
1960	5,247	53,781	10.25
1961	1,717	3,390	1.97
1962	2,206	5,224	2.37
1963	87	1,071	12.31
1964	475	5,313	11.19
1965	8,341	42,665	5.12

<sup>1/</sup> In thousands.

Appendix Table 9. Comparative age, length, index net catches and outmigration estimates of sockeye salmon smolt from the Kvichak River, 1960-1972.

Year of outmigration	Age I		Age II		24-hr. index points	24-hr. index catch	Outmigration estimate
	Percent	Mean length (mm)	Percent	Mean length (mm)			
1960	10	91	90	108	18.4	614,004	
1961	72	92	28	117	1.1	36,164	
1962	94	82	6	110	36.1	1,203,000	
1963	3	83	97	98	126.9	4,229,431	
1964	22	87	78	108	61.8	2,061,586	
1965	4	90	96	109	54.4	1,812,555	
1966	92	94	8	114	8.3	275,761	
1967	93	86	7	118	92.6	3,088,742	
1968	11	88	89	104	183.6	6,123,683	
1969	52	92	48	109	34.0	1,135,344	
1970	38	91	62	110	14.5	483,638	
1971	94	90	6	111	57.8	1,927,984	91,682,813
1972	1	80	99	106	42.6	1,421,104	67,575,075

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-6077, (TDD) 907-465-3646, or (FAX) 907-465-6078.